CUMULATIVE HYDROLOGIC IMPACT ASSESSMENT (CHIA)

WILLOW CREEK
AND
PRICE RIVER BASINS

Castle Gate Mine
ACT/007/004

Willow Creek Mine
ACT/007/038

Carbon County, Utah

April 12, 1996

I. INTRODUCTION

The Castle Gate Mine and proposed Willow Creek Mine are located approximately 5 miles north of the town of Helper, Utah, where the Price River and Willow Creek have cut deep canyons through the western Book Cliffs Coal Field (Figure 1). The two mines lie entirely within the Price River drainage, Willow Creek being a major tributary to the perennial Price River. The United States Geological Survey (USGS) has recorded no flow in Willow Creek many times, although year-round flow is common. The Price River and Willow Creek drainages extend north into Utah and Duchesne Counties. Intermittent discharge from Spring Canyon, a major drainage of the Book Cliffs west of the Price River, joins the Price River at Helper (Figure 2). Approximately 5 miles downstream of Helper is the city of Price, and from there the Price River flows southeast between the Book Cliffs and the San Rafael Swell to its confluence with the Green River. US Highway 6 and the mainline of the Denver and Rio Grande Railroad parallel the Price River through Price Canyon, and State Highway 33 follows Willow Creek canyon.

Many mines have gained access to coal in the western Book Cliffs Coal Field from the Price Canyon, Spring Canyon, and Willow Creek drainages. Other mines have accessed the coal in the Willow Creek area from the south through portals in the Book Cliffs escarpment. Generally, mining and other development has been limited to valley bottoms and adjacent lower valley slopes, with little development of high plateau and steep ridge areas.

During the first half of the twentieth century numerous mines were opened in the Book Cliffs west of the Price River. The Royal (Rolapp) Mine in Bear Canyon closed in the mid-1950's, and the nearby New Peerless Mine operated only from 1930 to 1931. In the Spring Canyon drainage the Peerless Mine and eight other mines located upstream from Sowbelly Gulch had all ceased operations by the 1950's. The Liberty Fuel (Latuda) Mine remained open until 1966 and the Spring Canyon Mine in Sowbelly Gulch was open until 1970. Operations in this western area that became part of the Castle Gate Mine operation included the #1 adit (Utah Fuel) in the west wall of Price Canyon, #2, #3 and #4 (Carbon Fuel/Castle Gate) in Hardscrabble Canyon, and #5 in Sowbelly Gulch. Two large shafts were excavated in Crandall Canyon (Figure 2).

On the east side of Price Canyon, the Ketchum Mine operated from near the turn of the century until the 1930's. The Utah Fuel No. 3 Mine opened in the early 1920's and closed in 1937 due to flooding of the Price River. Located at the mouth of Panther Canyon below the Willow Creek confluence, U. S. Fuel's Heiner Mine operated from 1914 to the 1930's.

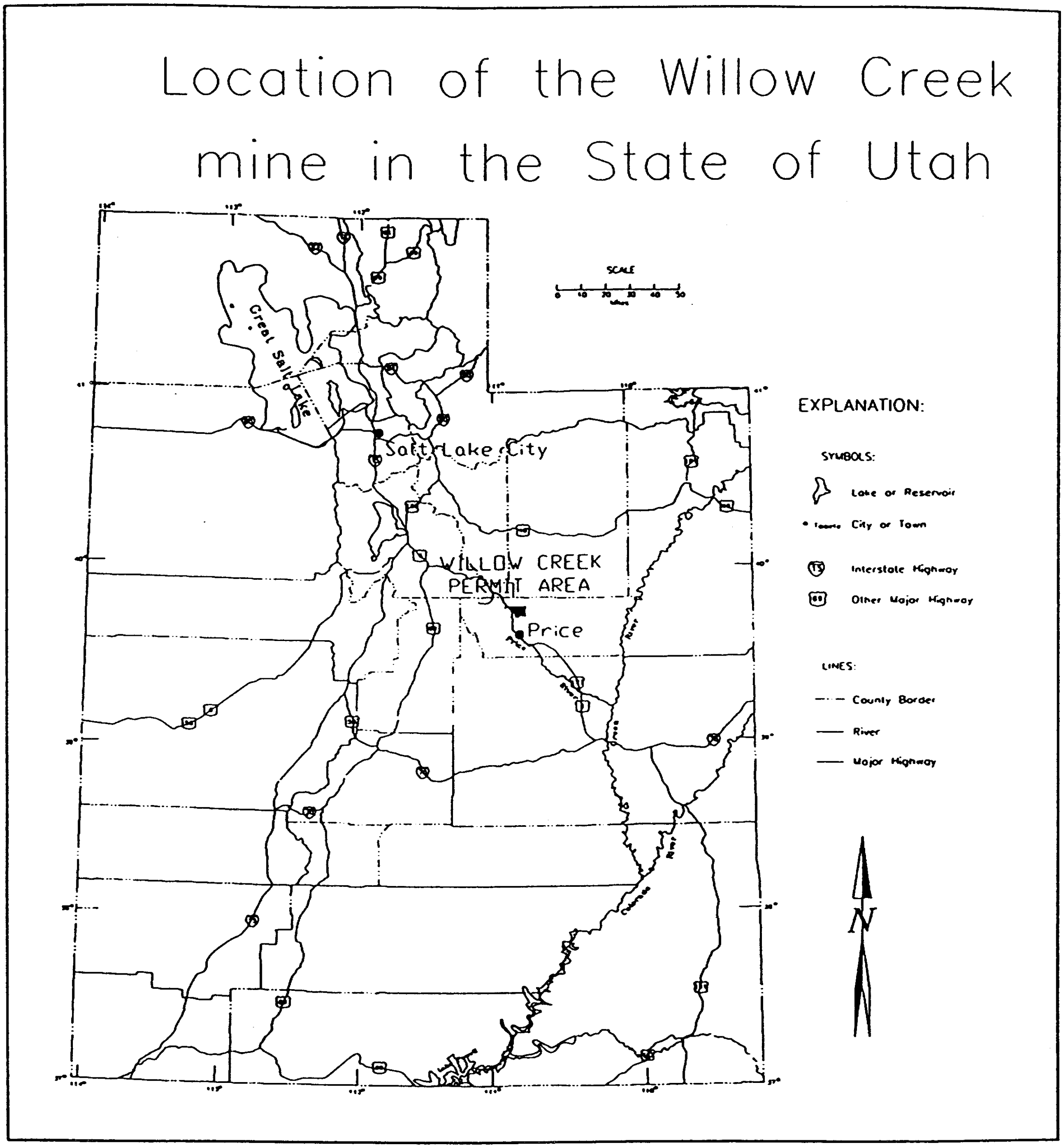

Figure 1 - Location Map

A loadout and coal prep-plant were built on the old Castle Gate townsite in the mid-1970's by McCullough Oil Company. A waste rock disposal site was built in Schoolhouse Canyon in the late-1970's by AEP, and a conveyor system was built to transport coal beneath Highway 89 and over the Price River, from the #1 adit to the prep-plant. These became part of the Castle Gate Mine operations.

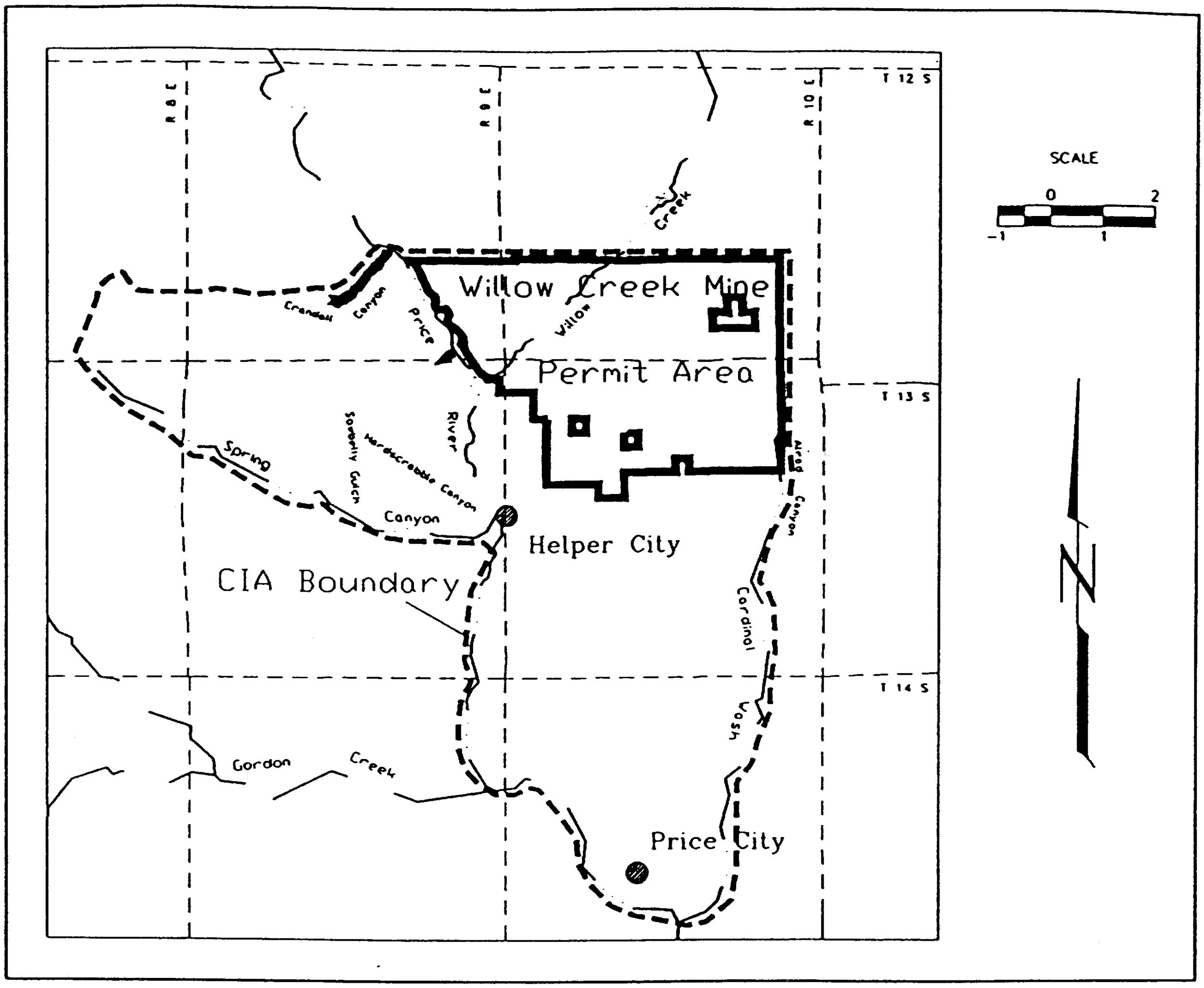

Figure 2 - CIA Boundary

Mining in Willow Creek drainage began in 1890 with the opening of the No. 2 mine by the Utah Fuel Company. Five portals for entry and ventilation were opened on the south bank of Willow Creek. A mine explosion in 1924 killed 172 miners, most of whom are buried in the nearby Castle Gate Cemetery. There was a second explosion in 1928. The No. 2 mine was operated continuously from 1890 to 1972: by Utah Fuel from 1890 to 1950, by Kaiser Steel from 1950 to 1952, by Independent Coke and Coal from 1952 to 1968, and by North American Coal Company from 1968 to 1972. The facilities and reserves were then sold to a succession of companies but the mine was not reopened. The No. 4 mine was opened in 1958 by Independent Coal and Coke and closed in 1970 by North American Coal Company. From 1938 to 1972 coal was transported from the No. 2 and No. 4 mines to an old coal preparation plant, located at the mouth of Schoolhouse Canyon, on narrow gauge rail that ran along the base of the bluffs and through tunnels on the north side of Willow Creek. Waste was disposed of along the canyon floor, and in adjacent canyons north of Willow Creek.

From 1938 to 1972 coal was transported from the No. 2 and No. 4 mines to an old coal preparation plant, located at the mouth of Schoolhouse Canyon, on narrow gauge rail that ran along the base of the bluffs and through tunnels on the north side of Willow Creek. Waste was disposed of along the canyon floor, and in adjacent canyons north of Willow Creek.

In 1971 most coal reserves in the western Book Cliffs were consolidated into a single unit by McCullough Oil Company, and mining activities were undertaken by the Braztah Corporation. Operations were transferred from Braztah to the Price River Coal Company (PRCC) in December 1979, Braztah and PRCC both being subsidiaries of American Electric Power (AEP). Price and Plantz (1987) state that coal was being mined at the Braztah Mines in the lower Willow Creek drainage during the 1979 to 1984 water years, when the USGS was monitoring streams in the coal fields of Utah. Castle Gate Coal Company (CGCC) obtained the PRCC western coal reserves (generally west of the Price River) in 1986, but the eastern reserves were transferred to Blackhawk Coal Company, another subsidiary of AEP.

Coal production from the Castle Gate Mine ended in 1989. Amax Coal Company purchased CGCC in 1991 and is the current operator of the inactive Castle Gate Mine. Cyprus Plateau Mining Corporation (CPMC) has acquired rights to the coal in the eastern reserves and has applied for a coal mining permit to open the Willow Creek Mine. Amax Coal Company and CPMC are both subsidiaries of Cyprus Amax Minerals Company.

The channel of Willow Creek was realigned and a pad and a portal face-up highwall constructed by Blackhawk Coal Company just to the northeast of the No. 4 Mine in 1974-1975 in preparation for underground mining, but portals and adits into the coal seam were never built. The graded area has been used for refuse disposal, equipment storage, and as a construction staging area. Under an agreement with Blackhawk Coal Co. executed in 1989, Utah Division of Oil, Gas, and Mining's (UDOGM) Abandoned Mine Reclamation Program (AMRP) used 9.5 acres of this pad and surrounding area for disposal of underground development waste that was transported to the site from several AMRP projects. AMRP assumed all responsibility for reclamation and regulatory compliance for this area. AMRP was able to reduce the faceup and return the surface to a more natural contour, establish vegetative cover and other erosion controls, and stabilize and enhance 1,500 feet of Willow Creek streambank.

Under current plans the old Blackhawk pad and portal area reclaimed by AMRP is to be redisturbed for construction of a mine pad and portals for the Willow Creek Mine. Amax Coal Company and CPMC also plan eventually to transfer the prep-plant, loadout, and Schoolhouse Canyon waste disposal site from the Castle Gate permit to the Willow Creek permit and reclaim the remainder of the Castle Gate Mine permit area.

Cyprus Plateau began acquiring baseline data in 1994 with the objective of obtaining a permit to mine coal south of Willow Creek in acreage acquired from American Electric Power (AEP). Additional acreage was subsequently acquired north of Willow Creek. The Castle Gate properties were purchased from Amax Coal Co. in 1994. Access for the proposed Willow Creek mine is planned to be through portals north of Willow Creek in the vicinity of the old Castle Gate cemetery. AEP had several portals in this area that were reclaimed after operations ceased. The Willow Creek Mine will possibly gain access to the coal by uncovering and reopening old portals.

This Cumulative Hydrologic Impact Assessment (CHIA) is a findings document involving an assessment of the cumulative impact of all anticipated coal mining operations on the hydrologic balance within the Cumulative Impact Area (CIA). The CHIA is not a determination if coal mining operations are each designed to prevent material damage beyond their respective permit boundaries when considered individually, but rather is a determination if there will be material damage resulting from effects that become cumulative outside the individual permit boundaries.

The objectives of a CHIA document are to:

1. Identify the Cumulative Impact Area (CIA). (Part II)

2. Describe the hydrologic system. (Part III)

3. Document the baseline conditions of surface and ground water quality and quantity. (Part IV)

4. Identify which hydrologic resources are likely to be impacted and determine which parameters are important for predicting future impacts to those hydrologic systems. (Part V)

5. Identify relevant standards against which predicted impacts can be compared. (Part VI)

6. Estimate probable future impacts of mining activity with respect to the parameters identified in 4. (Part VII)

7. Assess probable material damage. (Part VIII)

8. Make a statement of findings. (Part IX)

Material damage is not defined in either the Utah or Federal regulations. Criteria that are used to determine material damage to hydrologic resources in coal mining programs administered by other states or by the Federal Office of Surface Mining (OSM) include:

- Actual or potential violation of water quality criteria established by federal, state, or local jurisdictions.

- Changes to the hydrologic balance that would significantly affect actual or potential uses as designated by the regulatory authority.

- Reduction, loss, impairment, or preclusion of the utility of the resource to an existing or potential water user.

- Short term (completion of reclamation and bond release) impairment of actual water uses that cannot be mitigated.

- Significant actual or potential degradation of quantity or quality of surface water or important regional aquifers.

This CHIA has been prepared by the Utah Division of Oil, Gas, and Mining. It complies with Federal and Utah coal regulations as found in 30 CFR 784.14(f) and R645-301-729, respectively. The last CHIA for the area was prepared sometime between 1982 and 1989 for permitting of the Price River Coal Company (PRCC) complex. In addition to data sources cited in the References section and the Willow Creek Permit Application Package (PAP), the Mining and Reclamation Plans (MRP) for the Castle Gate Mine (ACT/007/004), Price River Coal Company (also ACT/007/004), and Blackhawk Coal Company (ACT/007/004) were used as information sources.

II. CUMULATIVE IMPACT AREA (CIA)

The Cumulative Impact Area (CIA) is shown on Figure 2. This is the area within which the actual and anticipated coal mining activities may interact to affect the surface and ground water. The CIA is determined based on anticipated mining activities, knowledge of surface and ground water resources, and anticipated impacts of mining on those water resources. Both surface and ground water CIA's have been delineated, but the ground water CIA lies entirely within the surface water CIA.

The only anticipated mine operations within the CIA are the proposed Willow Creek Mine, including the coal processing, loading, and waste rock disposal facilities at Castle Gate, and reclamation of the Castle Gate Mine.

Coal mining in Willow Creek and Price River areas dates back over 100 years. Previous mining has left areas of unreclaimed and unvegetated land in most watersheds. Hydrologic impacts from these previous operations are incorporated in the baseline information.

The surface water CIA extends upstream to the boundaries of the Willow Creek and Castle Gate permit areas, plus Deep Canyon that receives north-flowing drainage from the northeast corner of the Willow Creek permit area. The CIA extends downstream to where Spring Canyon joins the Price River from the west at Helper and to where Cardinal Wash joins the Price River from the east, approximately one mile downstream of the city of Price (Figure 2).

Hydrologic impacts from coal mining operations should be diluted by the Price River to the extent that the impacts will not be detectable downstream of the CIA. All surface water within the CIA eventually flows onto the outcrop of the Mancos Shale and water quality can be expected to deteriorate downstream from there. The impacts of coal mining operations on water quality will probably be minor in comparison to impacts from contact with the Mancos Shale.

There are coal mining and reclamation operations farther east along the Book Cliffs that have a potential to effect water quality in the Price River. The nearest of these, Andalex' Centennial Project, is drained mainly by Deadman Creek/Hayes Wash, which enters the Price River approximately two miles downstream of Cardinal Wash. However, the western edge of that project impinges on Alrad Canyon at the eastern edge of the Willow Creek CIA.

In the Wasatch Plateau, drainage from Cyprus/Plateau's Starpoint and Utah Fuel's Hiawatha mines reaches the Price River several miles below Hayes Wash by way of Miller Creek; other mines in the Wasatch Plateau do not drain to the Price River. There are also coal preparation or loadout facilities along the Price River. None of these permitted coal mining and reclamation operations have been included in the CIA.

A ground water CIA should include all areas between the anticipated mining operations and the aquifer discharge points. Ground water can be found in alluvial/colluvial, perched, and regional aquifers in the Price Canyon - Willow Creek area. Alluvial/colluvial systems correspond closely with the stream channels. Shallow, perched aquifers are recharged within relatively small areas around the seeps and springs where they discharge. The extent of the regional aquifer to the north is not known; however, the potentiometric surface should generally correspond to surface topography and rise to the north and the northern boundary of the ground water CIA has been made coincident with that of the surface CIA. The regional aquifer extends south to the outcrop of Mancos Shale at the base of the Book Cliffs. All ground water systems have been included in a single ground water CIA that coincides with the surface water CIA.

III. HYDROLOGIC SYSTEM

The area is characterized by rolling uplands and open parks above the steep sides of deeply incised canyons. Vegetation varies from Grassland-Sagebrush and Desert Shrub communities at lower elevations to Spruce/Fir/Aspen and Mountain Meadow communities at higher elevations. Areas north of the CIA are characterized by steep canyonlands with mixed pinon-juniper and sagebrush. These communities are generally used for wildlife habitat and livestock grazing. Alluvial fans covered with desert scrub line the Price River from its confluence with Willow Creek to Helper.

Land within the CIA is used for extensive underground mining activities, electric power generation, and transportation facilities. The remainder of the CIA generally consists of undeveloped lands utilized for low-intensity grazing, wildlife habitat, limited dispersed recreation, and very limited timber production. Anticipated post-mining uses are for wildlife habitat, grazing, and recreation. Water within the CIA is used for watering livestock and wildlife, mining coal, domestic use, fisheries, and recreation. Downstream, the water is additionally used for irrigation and industrial needs.

Climate

The closest active meteorological reporting station is located at PacifiCorp's Carbon Generating Station. Climatic characterization is based on historical climate data from this station and general regional climatic information. Evaporation and infiltration rates in the proposed lease and adjacent areas vary with vegetation, soil type, and time of year. Average annual potential evapotranspiration in the Price Canyon - Willow Creek area is 18 to 25 inches per year (Atlas of Utah, 1981). Much of the precipitation is lost to runoff, evaporation, and sublimation, minimizing the amount of water available for ground water recharge.

Temperature

Generally, the climate of the area is temperate. Temperatures in the area normally reflect a typical seasonal pattern with gradual warming beginning in mid to late-March, high seasonal temperatures in July and early August, a gradual cooling beginning in late August to early September, and seasonal lows in late-December through mid-February. Summer high temperatures range from 60° to 75°F (15° to 24°C) and winter lows typically vary from 10° to 20°F (-12° to 7°C). The recorded high temperature for the area is 90°F (32°C) and the low is -10°F (-23°C). The average frost-free period in this area ranges from approximately 60 to 120 days.

Precipitation

The climate in the area is arid to semi-arid, with annual precipitation ranging from 13 to 20 inches and averaging 14.8 inches. Monthly average precipitation ranges from 0.65 inches (June) to 1.86 inches (September) and the high average monthly snowfall is 9.9 inches (December). The majority of the precipitation occurs as snowfall during the months of December, January, February, and March. Rainfall comes typically as brief, high-intensity thunderstorms, with most thunderstorm activity occurring during late summer and early fall and peaking in August. Price and Arnow (1979) estimate probably less than 5% of the precipitation recharges the ground water system, which would be 0.6 to 1 inch per year.

Wind

Monitoring at the Carbon Generating Station has not included wind speed or direction. General regional information indicates that prevailing winds are from the west and northwest, and average wind velocities generally do not exceed 20 miles per hour. During the winter the prevailing wind direction can shift for extended periods and blow from the northeast. Exposure of plateau and ridgeline areas may produce higher wind velocities than in more sheltered slope, basin, and valley areas. Surface air movements are strongly affected locally by natural drainage patterns and diurnal temperature variations (up and down canyon winds).

Surface Water

Perennial streams in the area are the Price River, Willow Creek, Sulphur Canyon creek, and Summit Creek, and a major intermittent stream flows through Spring Canyon. Mathis, Deep, and Buck Canyons and the main stem of Antone Creek exhibit perennial flows in certain reaches with intermittent or ephemeral flows in others. All other area drainages are characterized by flow in response to precipitation only.

Headwaters of the Price River are north and west of the proposed Willow Creek Mine, along the eastern escarpment of the Wasatch Plateau. Total length of the Price River drainage is roughly 85 miles. Elevations range from approximately 9,800 near Scofield Reservoir and Soldier Summit to 5,800 feet at Helper and 4,100 feet at the confluence with the Green River. The Price River watershed above USGS monitoring station 09313000 (near the town of Heiner) drains an area of approximately 415 square miles (265,600 acres) and includes three major tributaries: White River, Beaver Creek, and Willow Creek.

Willow Creek originates on the Green River Formation of Tertiary age at an altitude of about 9,200 feet, on the southern flanks of Reservation Ridge on the West Tavaputs Plateau. The headwaters are east and north of the proposed Willow Creek Mine permit area. Willow Creek drains an area of approximately 77.4 square miles (49,536 acres), and drainage length is approximately 9.3 miles. The stream descends more than 3,000 feet through progressively older geologic formations to its confluence with the Price River at about 6,100 feet. Willow Creek is one of the primary tributaries of the upper Price River drainage. The confluence of the two streams is on the coal-bearing Blackhawk Formation.

Between Emma Park and its confluence with Price River, the Willow Creek drainage is characterized by steep canyonlands with mixed pinon-juniper and sagebrush. Intermittent and ephemeral tributary drainages to Willow Creek that drain the east and northern slopes of the Book Cliffs in the CIA include Dry, Mathis, and Deep Canyons. Stream flow from these drainages is commonly very low. Willow Creek traverses Emma Park, an open terraced park that separates the Book and Roan Cliffs, where vegetation is a sagebrush/grassland community. Summit Creek, a major perennial tributary to Willow Creek, drains Emma and Whitmore Parks and adjacent portions of the Book and Roan Cliffs, but not any portion of the CIA. Upstream of Emma Park, Willow Creek drains a section of the Roan Cliffs, which are characterized by rolling uplands with mixed coniferous/aspen forests.

Spring Canyon creek originates at an altitude of about 9,800 feet, at the juncture of the Wasatch Plateau and Book Cliffs. The canyon descends approximately 4,000 feet to its confluence with the Price River. Burnt Tree Fork, Ciochetto and Rains Canyons, and Robinson, Gilson, and Sowbelly Gulches are the main tributary drainages.

There are no natural or man-made lakes or reservoirs within the CIA. Several small man-made sedimentation ponds, associated with past and present coal mine facilities, are located within the CIA. These include ponds in the former Blackhawk Coal Company permit area adjacent to Willow Creek, the Price River Coal Company permit area adjacent to the Price River, and the Utah Power and Light Carbon Generating Station facilities adjacent to the Price River. The sedimentation structures exist solely for containment and retention of disturbed area runoff, which allows settling of suspended solids prior to discharge of runoff to natural drainages. Active sedimentation ponds are monitored on a regular basis to verify compliance with regulatory provisions and effluent discharge limitations. Because they are utilized for temporary retention of storm water runoff, no water rights or beneficial uses are associated with existing sedimentation structures.

There are a number of very small stock-watering ponds scattered throughout the area, typically in the headwaters of ephemeral watersheds. Stock ponds are commonly associated with a spring, and spring/stock tank combinations in or adjacent to the CIA can be found in Panther, Deep, Buck, and Mathis Canyons, and possibly Dry Canyon.

Surface Water Usage

A number of individuals, water user associations, government agencies, and corporate entities hold surface water rights on the Price River, Willow Creek, and some of the larger tributary drainages. Beneficial surface water use is generally limited to; 1) Domestic water supply; 2) Industrial uses; and 3) Limited agricultural use.

The Price Water Supply and Treatment Plant is located next to the Price River, across from Bear Canyon and near the abandoned Royal townsite. The Price River and associated tributaries above the water treatment plant are considered a municipal watershed. Areas downstream from the plant are not within the municipal watershed. The Willow Creek and Castle Gate permit areas include both municipal and non-municipal watershed areas.

Agricultural uses include small stock watering ponds in the upper reaches of many of the small ephemeral tributaries. Water supply wells in alluvium along the Price River produce from the shallow unconfined aquifer that is interconnected with the river. Along the Price River valley, especially near Heiner, Martin, and Helper, numerous individuals and corporations have significant water rights that are used for irrigation purposes.

Cyprus Plateau Mining Corporation (CPMC) has rights to water from the Price River through Amax Western Coal Company, and PacifiCorp has rights to water from the Price River and Willow Creek. Cooling water for the PacifiCorp Carbon power generating station comes from the "UGW" well located next to the Price River near the abandoned Royal townsite.

The area covered by the willow Creek MRP provides potential habitat for eighteen fish species, and there are potentially 67 species of fish in the Price River and Willow Creek drainages. Willow Creek and Price River are considered to be a Class 4 fisheries by UDWR, which are streams with low recreational fishing potential. Game fish species expected to occur in these two streams include rainbow trout, Yellowstone cutthroat trout, and brown trout. Also, channel catfish are expected in the Price River.

With the exceptions of the Price River and the extreme lower reaches of Willow Creek, the rugged broken terrain and high intensity, short duration flows typical of area drainages result in small, deeply incised drainages with little or no defined floodplain. Floodplain areas of both lower Willow Creek and the Price River around Castle Gate have been extensively disturbed and significantly altered by historic mining operations, highway and railroad construction, residential development at the now abandoned townsites of Royal and Castle Gate, and construction of the existing PacifiCorp Carbon Power Station and associated facilities. Based on available information, these floodplain areas have no history of irrigation or farming.

Ground Water

Ground water is found principally in four configurations within the CIA: numerous small, localized perched systems related to discontinuous sandstone lenses in the Blackhawk Formation, a continuous regional system in the coal seams and adjacent rocks of the lower Blackhawk Formation and the underlying sandstones, a stored mine water system, and an alluvial/colluvial aquifer system. A principal factor influencing the distribution and availability of ground water in these systems is the geology.

There are a number of very small stock-watering ponds scattered throughout the area, and they are typically associated with a spring in the headwaters of ephemeral watersheds such as Panther, Deep, Buck, Mathis, and Dry Canyons. Water rights have been filed on some of the stock ponds.

Thin marginal soils and limited vegetative cover result in rapid runoff and consequent low infiltration rates, especially in steep slope areas. Reported net infiltration rates for unfrozen soils under similar conditions to those found in the region are about 0.50 inches per day. Price and Arnow (1979) estimate probably less than 5% of the precipitation recharges the ground water system, which would be 0.6 to 1 inch per year.

Geology

The area is characterized as deeply incised "plateau topography" with flat-topped ridges that rise above adjacent high desert lands. Moderately nonresistant, fine-grained units interfinger with thick, resistant sandstone units. Erosion produces moderate to steep weathered slopes interspersed with vertically exposed resistant ledges and cliffs. The regions characteristic high topographic relief incised by steep-walled canyons is the result of extensive erosion along zones of weakness. Surface elevations vary from 5500 feet to 9000 feet within the CIA, with Blackhawk Formation outcrops forming most of this relief.

Major canyons are Price River Canyon that drains from the north-west and Willow Creek canyon that drains from the north-east into the Price River. Elevations in the general area range from over 9,000 feet above sea level on the tops of the flat-topped ridges to about 5,500 feet above sea-level along the Price River south of the CIA.

Stratigraphy and General Lithology

Stratigraphy Lithology of the Book Cliffs and Wasatch Plateau Coal Fields consists of a thick accumulation of Upper Cretaceous and Tertiary strata (Figure 3). The Upper Cretaceous sediments of the section were deposited along the western margins of a north-south oriented interior seaway. A rapidly rising mountain belt to the west supplied clastic material for shoreline construction in wave-dominated delta systems. Throughout Cretaceous time, this seaway underwent a series of onlap (transgressive or advancing) and offlap (regressive or retreating) phases that deposited a number of broad delta and prodelta sheet sandstones. These sandstone tongues thicken westward and grade into back barrier, coastal and delta plain, and continental deposits. Seaward there is thinning and fining of sediment sizes. Major coal deposits found in Utah are usually formed immediately landward of shoreline delta sandstone pinchouts and on top of these offlap delta deposits.

Landward of the often thick shoreline coal accumulations, delta plain depositional influences such as splays, small channels, and levee deposits have generally created a series of splits in the coal section. Additional transgressive-regressive events commonly invaded the swamp systems and left interdeltaic features such as storm washover fans, tidal inlet deltas, and lagoonal muds. Coal deposited in these environments are often thinner due to decreased time available for peat deposition. Coals that formed on delta sandstone sheets are usually very planar and continuous whereas coal seams found in the delta or lower coastal plain are much more likely to exhibit rolls or undulations, scouring by fluvial channels, and discontinuous or lenticular geometry.

In ascending order the strata exposed in the area are the Masuk Shale member of the Mancos Shale, the coal-bearing Blackhawk Formation, the unconformably overlying Castlegate Sandstone, the Price River Formation, and the North Horn Formation.

The Mancos Shale consists of marine shales interbedded with sandstones and minor amounts of limestone. The Mancos Shale, which forms the valley floor and lower slopes of the prominent cliffs, is over 4,000 feet thick in the area and consists primarily of interbedded marine shales. The Masuk Shale, the uppermost member of the Mancos, grades upward into the basal sandstones of the Blackhawk Formation, and westward thinning wedges of Mancos Shale intertongue with the sandstones. The Mancos is a clay-rich unit and the shale beds are good aquicludes, with low horizontal and vertical permeabilities even near faults.

The base of the Blackhawk Formation is locally comprised of five cliff-forming sandstone members, the Panther, Storrs, Spring Canyon, Aberdeen, and Kenilworth Sandstones, in ascending order. The basal Blackhawk sandstones were deposited in a barrier-beach environment and intertongue with the Mancos Shale below. The sandstone tongues thicken westward and grade into the backbarrier, coastal plain, and deltaic deposits of the Blackhawk Formation. The Panther, Storrs, and Spring Canyon sandstones merge to the west into one massive sandstone unit, up to 1000 feet thick, called the Star Point Sandstone. Lithologies are usually comprised of gradationally sorted sandstones; medium-grained and cross-bedded at the top and fine-grained to silty at their base. These sandstones are generally poor aquifers, due in part to low permeability shale lenses, but ground water transmission is greatly enhanced where these rocks are faulted, fractured, and jointed.

System	Series	Stratigraphic Unit		Thickness (feet)	Description
TERTIARY	Paleocene	Wasatch Group	Flagstaff Limestone	200 - 1,500	Dark yellow-gray to cream colored, dense, cherty, lacustrine limestone with thin interbeds of gray and gray-green shale. Minor amounts of sandstone and volcanic ash, with pink calcareous siltstone at the base in places. Ledge former. Many springs originating from this unit have large discharge rates shortly after snowmelt with rapid decrease, indicating large transmissivity and small storage capacity characteristic of solution-cavity ground water systems.
CRETACEOUS	Danian? / Maestrichtian		North Horn Formation (Lower Wasatch)	500 - 2,500	Variegated shale and mudstone interbedded with sandstone, conglomerate, and limestone, all of fluvial and lacustrine origin. Ledge former. Many springs originate where low permeability layers intersect the land surface, indicating perched ground water systems.
	Campanian	Mesaverde Group	Price River Formation	500 - 1,000	White to gray, gritty, calcareous to argillaceous sandstone interbedded with subordinate carbonaceous shale and conglomerate. Ledge and slope former.
			Castlegate Sandstone Member	100 - 500	Coarse grained fluvial sandstone, pebble conglomerates, and subordinate zones of mudstone. Cliff former. High permeability but largely unsaturated. Seeps and springs with seasonal variability are common.
			Blackhawk Formation	900 - 1,400	Fine to medium grained, thin to thick bedded, massive fluvial channel sandstone, alternating with subordinate siltstones, carbonaceous shales and mudstones, and coal. Fluvial channel sandstones are more common in the upper portion. Thick, discontinuous coal seams in the lower 500 feet. Slope former with sandstone ledges. Poor aquifer material even where faulted due to the discontinuous nature of the channel sands and the swelling properties of the shales. Relatively low transmissivities. Springs have seasonal variability. In-mine flows of up to 200 gpm with rapidly decreasing discharges. The lower Blackhawk and Starpoint are considered to be one aquifer.
			Kenilworth, Aberdeen, *Spring Cyn., *Storrs, and *Panther Sandstones (*Star Point)	90 - 1,000	Fine to medium grained, massive, moderately well sorted coarsening upward sandstones. Cliff forming. Subordinate siltstones and carbonaceous shale. Intertongues with the Mancos Shale below and the Blackhawk Formation above. Uppermost portion contains fluvial channel sandstones. Generally poor aquifer material yielding < 10 gpm. Springs have low seasonal variation, indicating large aquifer storage coefficient. Transmissivities are relatively large where rock is fractured and faulted with yields up to 300 gpm.
	Santonian	Mancos Shale	Masuk Shale	300 - 1,300	Slope forming sandy marine shales interbedded with sandstones and minor amounts of limestone. Grades upward into and intertongues with the overlying Star Point Sandstone. A good aquiclude.

After Doelling, 1972

Figure 3 - Generalized Stratigraphic Section

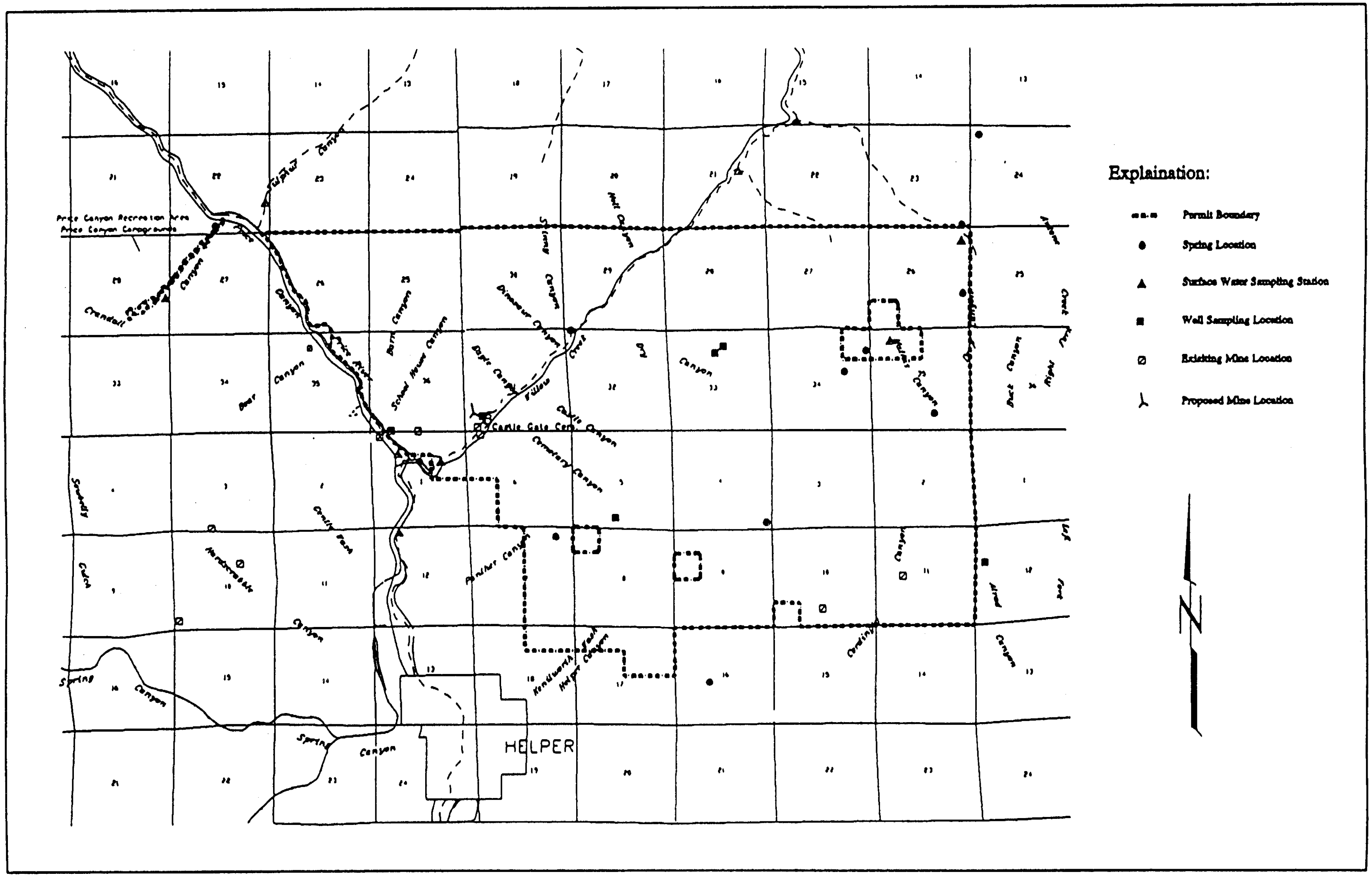

Figure 4 - Monitoring Points

The aggregate thickness for the Blackhawk Formation in the area is roughly 900 to 1,400 feet thick. The Blackhawk Formation is the primary coal-bearing formation in the Book Cliffs and Wasatch Plateau Coal Fields. The important coal seams occur in the lower 500 feet. Thick and laterally extensive seams are closely associated with shoreline barrier-beach sands. Resting on and landward of the barrier-beach sandstones are lenticular sediments including reworked tidal channel-fill sandstones, fluvial sandstones, mudstones, siltstones, claystones, and coals deposited in backbarrier, lower coastal plain, and deltaic environments. Claystones contain high percentages of montmorillonite and other swelling clays.

There are five coal seams of economic interest at present. These seams are the basal A (Castlegate A/Aberdeen) Seam, generally developed on the Aberdeen Sandstone, the B Seam that splits off the A Seam, the C Seam at the base of the Kenilworth Sandstone, the Kenilworth (K) Seam developed on and shorewards of the Kenilworth Sandstone, and the D Seam approximately 100 feet above the Kenilworth Seam.

Fluvial channel sandstones are found in the lower Blackhawk but are more frequent toward the top of the formation. These sandstones are local in extent, generally fine grained, and well cemented. They have localized high clay content. The discontinuous character of these channel sandstones and the abundance of clay throughout the Blackhawk Formation produce perched aquifers and favor formation of local flow systems that discharge through numerous seeps and springs.

Unconformably overlying the Blackhawk Formation are the massive, fluvial pebble conglomerates and coarse grained sandstones of the Castlegate Sandstone, which is the basal member of the Price River Formation. The Castlegate Sandstone is good aquifer material, with seeps and springs common at the Castlegate-Blackhawk contact. In the Price River area the Castlegate can be subdivided into three generic members with an aggregate thickness of about 630 feet. The Castlegate represents offlap coastal and fluvial deposition during the rapid retreat of the Upper Cretaceous Seaway in the area. Castlegate Sandstone is exposed along the ridge in the northern part of the CIA. Tertiary rocks of the Wasatch Group form the uppermost exposures in areas south of the CIA.

The remainder of the Price River Formation is comprised of fine-grained sandstones and slope-forming mudstones and siltstones totaling approximately 650 feet in thickness. Deposition of the upper Price River Formation took place from southwest to northeast indicating major reorientation of area drainage patterns between the periods represented by the Castlegate Sandstone and the Price River Formation, and the contact appears unconformable at some locations.

The North Horn Formation, the youngest consolidated rocks exposed within the CIA, has a total thickness of about 2,400 feet. This unit mainly consists of basal mudstones (170 feet), a middle zone of sandstones (860 feet), mixed thin limestones and claystones (330 feet), and an upper 1,000 foot sequence of sandstones and limey sediments. Lenticular, cliff-forming (10 feet) sandstones comprise about 10 to 15% of the section. The basal 170 feet of the formation represents the uppermost of the Mesozoic strata in the area. Tertiary (Paleocene) fluvial and lake deposits appear from the top of the basal mudstones to the top of the section.

Structure The CIA lies at the western end of the Book Cliffs at a three-way structural transition zone between the Colorado Plateau, the Uinta Basin, and the Wasatch Plateau structural provinces. This places the western Book Cliffs coal reserves at the north end of the north-plunging limb of the San Rafael Swell and north of the north-west trending strike-slip Fish Creek Graben that delineates the local northern border of the hypothesized Castle Valley thrust. The location and relationship of the reserve block to these regional features may account for the lack of significant structural features, including faulting and folding within the western Book Cliffs (Greg Hunt, consulting geologist, in Willow Creek PAP).

Average strike of strata within the proposed Willow Creek permit area ranges from N 80° W in the east to N 85° W in the northwest. Dip averages 8.5° N-NE. This attitude is a result of the location between the north-plunging end of the San Rafael Swell and the south flank of the Uinta basin. Localized dips up to 15° occur as a result of depositional variations such as the limited area where the Kenilworth Seam dips 15° west, having been warped or draped over the landward pinchout of the Kenilworth Sandstone.

Faults

The western Book Cliffs area was apparently isolated from geologically recent tensional forces by the Fish Creek Graben to the west. Existing fractures encountered during drilling or other exploration work appear to be relatively tight with some evidence of fracture fillings. North-south trending structure is quite minor (Greg Hunt, consulting geologist, in Willow Creek PAP). In addition to examining mine maps and drill data, CPMC learned from discussions with miners who worked in the Castlegate No. 2 Mine that faults large enough to impact mining operations do not occur within the old mine works and probably do not exist within the Willow Creek reserve block.

Doelling (1972) mapped an inferred or poorly defined fault, with unknown throw, striking approximately N 50° E through the center of Sections 4 and 9, T. 13 S., R. 10 E., extending from Panther Canyon to the head of Dry Canyon. No evidence of this structure is known from underground workings in the area, and CPMC's inquiries to the Utah Geological Survey (UGS) did not find any original data or further documentation to support mapping of a fault at this location.

Joints and Cleats

A fracture study of the Willow Creek area was completed in late 1991 (Anderson) and additional joint and cleat data have been collected by CPMC from underground exposures. Anderson's work, based on sixteen locations, indicates that the joint trend on the Willow Creek property is N 60° W. A secondary set of joints trends about N 75° E. Most dips of discontinuities are 5° to 7° off vertical. The coal cleat was found to have a very strong N 60° W face cleat and a butt cleat about N 35° E. Density of fractures was highly dependant upon the type and thickness of the bed in which the trends are measured. Thinner beds and finer grained rocks (siltstones and mudstones) have a tendency to have a greater density of joints than thicker beds and homogeneous sandstones. Many joint sets are truncated by shale partings and other vertical changes in lithology.

A cursory examination by Anderson in the Price River area found that typical joint densities were:

Formation	Range	Average
Price River Fm.	1/1 feet - 1/8 feet	1/1.5 feet
Castlegate SS.	1/1 feet - 1/30 feet	1/2 feet
Aberdeen SS	1/3 feet - 1/10 feet	1/3 feet
Spring Canyon SS	1/3 feet - 1/13 feet	1/3 feet

Joint continuity in the proposed Willow Creek permit area is not pronounced. Cross-cutting major joint trends appear to be spaced about every 200 feet in massive sandstones. Observations of mudstone roof of coal seams where exposed, revealed joint spacings ranging from 0.1 foot to over 3.0 feet with high density zones appearing only periodically.

Notes on fractures and fracture filling in core descriptions prior to the 1994 drilling project is sparse, but CPMC found some holes document compactional slickensides in clay-rich zones and calcite filling of open fractures in sandstones and sandy siltstones. CPMC's drill hole W94-12-1 (Alrad Canyon) was cored intermittently from 140.0 to 398.7 feet without the documentation of a single joint discontinuity. Core from hole W94-5-1 in the Panther Canyon area displayed only very rare irregular vertical fractures that may have been drilling induced. Coring in hole W94-31-1 (Willow Creek fan site) recovered samples of sandstone with smooth or irregular fractures spaced at intervals down the hole. Rarely fractures were found to be filled with calcite but were usually open and rough. Site W94-33-1, in Dry Canyon, was cored from 900 feet to 1,275 feet with only one encounter with an irregular/rough joint at 1,131 feet. Occasional compactional slickensides were noted in clay-rich mudstones (Willow Creek PAP).

The Kenilworth and A Seams exhibit a well-developed face cleat oriented roughly N 60° to N 70° W. Cleat spacing generally ranges from 0.1 to 0.4 feet. The butt cleat is very poorly developed. In-filling on cleats is rare but where it occurs is either calcite or gypsum. Available photos of the old mine works show strong rib lines and wide entry spans with little sign of deterioration after 25 to 75 years of exposure under varying overburden depth.

Inspection of mine works by CPMC during 1992 - 1993 showed coal cleats to be present and well-developed. Former miners who worked in the Castlegate No. 2 Mine commonly told CPMC that they could recall almost no cleats in the seams, but they consistently recalled that a continuous miner could cut east-west much easier than other directions, indicating a limited cleat did exist (Willow Creek PAP).

Aquifer Characteristics

Information obtained from borehole drilling and well installation, geologic and geophysical logging, observations of water during borehole drilling, aquifer testing, routine water level monitoring, and routine ground water quality analyses has been used by CPMC to characterize ground water aquifers within and adjacent to the proposed Willow Creek Mine. Four primary aquifer systems have been identified:

- Alluvial/Colluvial Aquifer System
- Perched Ground Water System
- Stored Mine Water System
- Regional Ground Water System

Alluvial/Colluvial Aquifer System The alluvial/colluvial aquifer system consists of shallow, unconfined ground water in the limited alluvial/colluvial deposits associated with surface drainages in the area. These aquifers are closely tied to the surface water systems, with ground water recharge occurring during periods of high flow and ground water discharge becoming more pronounced during periods of low flow as stream levels drop below the water table. The regional aquifer system may also be a source of recharge to alluvial/colluvial systems; however, the extensive underground mine workings that locally drain the regional aquifer and the low permeability of the rocks of the regional aquifer probably limit the amount and significance of recharge to alluvial/colluvial aquifers from the regional aquifer.

The only alluvial/colluvial aquifers of any significance in the CIA occur along the channels of the perennial drainages of the Price River and Willow Creek and are generally confined to the active stream channel, immediately adjacent areas, and any hydrologically connected inactive or abandoned channel segments. In the smaller drainages, these alluvial/colluvial deposits are very narrow and may store and transmit relatively minor amounts of ground water.

In 1994 CPMC bored fifteen holes in the shallow alluvial/colluvial aquifers of the Price River and Willow Creek to evaluate foundation conditions at the Castle Gate coal prep plant, the AMRP Blackhawk reclamation site, and proposed facilities along Willow Creek. Ground water was encountered in three of the holes. Ground water at the AMRP site appeared to be at least 20 feet below the buried refuse and to be flowing towards Willow Creek. Thickness of alluvial/colluvial material along Willow Creek was found to vary from a few inches up to five feet, and in the Price River drainage up to approximately 60 feet. The alluvial/colluvial materials consisted of loose to compact brown sandy silt with gravel, cobbles, and boulders. Relatively coarse, generally high permeability colluvial material dominates the alluvial/colluvial deposits because steep terrain and brief, high-intensity runoff result in high erosion and sediment transport rates.

Price and Wadell (1973) indicate that wells completed in the Price River alluvial/colluvial deposits frequently provide sustained yields of up to 500 gpm. No wells exist in the Willow Creek alluvial/colluvial deposits and specific aquifer test information is not available, but expected ground water yields along Willow Creek would be significantly less than along the Price River because of lower surface water flow volumes and thinner alluvial/colluvial deposits.

Perched Ground Water System Perched aquifers in the Wasatch Plateau and Book Cliffs typically occur in numerous small, localized lithologic units that have sufficient permeability to store and transmit ground water. They are found at shallow depths in the Flagstaff, North Horn, and Price River Formations and upper portions of the Blackhawk Formation, which are dominantly interbedded sequences of shale, siltstone, and fluvial channel sandstones. Fine grained, well cemented sandstones are typically the water-bearing unit with lower permeability siltstones and relatively impermeable shales acting to confine ground water movement. Burned-out coal zones also have good permeability and can be perched aquifers. Isolated perched water tables may occur deeper in the rock, surrounded by unsaturated strata.

Perched aquifers in the Wasatch Plateau and Book Cliffs are of limited areal extent and thickness because of the discontinuous or lenticular shape of the sandstone bodies. Variations of permeability within the sandstone bodies further limit storage and movement of water, and perched aquifers can be breached and truncated by deeply eroded surface drainages. The discontinuous character of the sandstones and the abundance of clay throughcut the formations favor formation of local flow systems that discharge through numerous small seeps and springs. Perched aquifers are separated by unsaturated rock.

Discharge from perched aquifers is primarily from seeps and springs at outcrops of sandstone-shale interfaces. Discharge from the perched ground water system to the regional ground water system can also occur due to fracture or fault related secondary permeability; however, such vertical movement is probably not significant in the CIA because of the lack of faulting and fracturing.

Perched aquifers are generally recharged within small areas in the immediate vicinity of the seeps and springs where they discharge. Recharge is almost exclusively by infiltration of direct precipitation and snowmelt, and discharge from these aquifers closely tracks precipitation rates. The combination of steep terrain and relatively low permeabilities, which probably limit infiltration to less than 5 percent of annual precipitation (Price and Arnow, 1979), and the limited areal extent of the water-bearing strata result in low recharge rates to the perched ground water system.

CPMC identified 3 active seeps and 12 active springs in the proposed Willow Creek permit and adjacent areas, which all appear to discharge from the perched aquifer system. Measured seep and spring discharge typically varies from negligible flow to approximately 5 gpm with isolated flows of up to 10 gpm. Discharge from the perched ground water system exhibits significant seasonal variation with maximum discharge following spring snowmelt and many springs and seeps drying up during late summer and early fall.

Subsurface ground water was intercepted in each of CPMC's 1994 exploratory drill holes, at depths ranging from 85 feet (in a burn zone level with an adjacent dry streambed) to 1,300 feet (interbedded sandstones approximately 45 feet below the top of the Aberdeen Sandstone), and at flow rates of 1/4 to 7 gpm. The well in Dry Canyon (B331/B331A) encountered a significant amount of natural gas and 15-20 gpm ground water from an interval of thinly-bedded sandstones at a depth of 900 feet, with natural gas flow probably generating the higher ground water flow. Water was found in the Aberdeen and Kenilworth Sandstones, other unidentified sandstones, and in the burn zone already mentioned.

In the Willow Creek water monitoring well, the static water level was measured at a depth of about 95 feet in a thick (20 foot) sandstone just above the D Seam. This level is close to the natural stream level of nearby Willow Creek and may represent either a perched aquifer or the regional aquifer system.

Regional Aquifer System The regional aquifer system includes the coal bearing zones and the barrier-beach sandstones of the lower Blackhawk Formation and extends into the underlying Mancos Formation. The primary water-bearing unit is the Aberdeen sandstone, but the regional aquifer is not tied to any specific stratigraphic unit. Because it includes the primary coal-bearing sequence, the regional aquifer system will be directly affected by the mining operations. Limited recharge and generally low permeabilities result in minimal ground water storage and movement in the regional aquifer system and limit its significance in the regional hydrologic system.

The regional aquifer is unconfined. Most stratigraphic units associated with the regional aquifer system transmit water poorly, with fine to medium grain size, cementation, and cross-bedding contributing to low overall permeabilities; however, all units lying below the normal water table and having sufficient permeability contain and transmit ground water to some degree. Water table elevations generally form a subdued replica of surface topography, and elevations of the regional water table in the western Book Cliffs are expected to increase northward: in addition structural dip is north to northeast, so to the north the regional water table is anticipated to lie successively higher in the stratigraphic section. Drainage into the incised, deeply eroded canyons and into mines can lower the regional water table surface locally.

Hydraulic conductivity values measured in water-bearing units in wells MC-205 and MC-206 (Figure 4) are on the order of $1x10^{-7}$ to $1x10^{-6}$ cm/sec ($2.8x10^{-4}$ to $2.8x10^{-3}$ ft/day). Measured transmissivities for these wells range from 5 to 70 gpd/ft. Similar values of hydraulic conductivity and transmissivity were found in the coal-bearing sequence of the Blackhawk Formation in well MC-207, near the Kenilworth adit in Crandall Canyon. Aquifer tests in wells B121 and B331A indicated hydraulic conductivity values of $3.0x10^{-7}$ cm/sec and $4.6x10^{-7}$ cm/sec ($8.5x10^{-4}$ and $1.3x10^{-3}$ ft/day), respectively.

Based on pump tests and core analyses from the Trail Mountain area in the Wasatch Plateau, transmissivity of the regional aquifer in the coal bearing zones and the barrier-beach sandstones of the lower Blackhawk Formation probably ranges from 20 to 200 ft^2/day. Storage coefficient probably averages about 10^{-6} for confined conditions and about 0.05 for unconfined (Lines, 1985, p. 15). Horizontal and vertical hydraulic conductivities in Starpoint Sandstone from the Skyline Mines area in the Wasatch Plateau, as measured by Core Laboratories, Inc. in Dallas, Texas, are on the order of 10^{-2} ft/day. Sandstones in the Blackhawk Formation have hydraulic conductivities similar to those of the Starpoint Sandstone. Horizontal hydraulic conductivities in shales of the Blackhawk range from no measurable permeability to 10^{-8} ft/day, and in siltstones from 10^{-9} to 10^{-7} ft/day. Vertical hydraulic conductivities of shales and siltstones may be greater or smaller but are within one order of magnitude of the corresponding horizontal hydraulic conductivity (Lines, 1985, Table 3).

Recharge to the regional aquifer system appears to occur primarily where outcrop zones are exposed to direct precipitation and near-surface infiltration. Recharge percolates from the surface downward until shale is encountered, and then moves downdip following discontinuous but more permeable sandstones. Water either continues to move downdip until it is discharged at the surface or resumes vertical flow where more permeable zones are encountered, and recharge eventually reaches the regional aquifer. Vertical ground water movement through the overlying sediments is minimal due to the low permeability of the overlying units and the presence of relatively impermeable shales. Steep slopes and relatively small outcrop exposure areas are two factors that limit recharge. Faults and fractures do not seem to be important ground water conduits in the western Book Cliffs.

Some recharge of the regional aquifer system may occur where the associated formations are exposed in deep canyons and come into direct contact with surface discharge or the alluvial/colluvial aquifer system: such exposures are not common in the area. Such direct recharge is limited by low permeabilities.

The regional aquifer extends to the outcrop of Mancos Shale along the base of the Book Cliffs. Water is unable to flow downward through the Mancos in any significant amount but will flow laterally through more permeable overlying strata until it discharges at the surface. The regional aquifer discharges at springs along the Blackhawk - Mancos contact in Spring Canyon, but there are no springs at this contact in other areas of the western Book Cliffs. Within and downdip of the proposed Willow Creek permit area, discharge from the regional aquifer system appears to be limited to inflows to the stored mine water system where mine workings extend below the potentiometric surface. Leakage to the Mancos and other units underlying the regional aquifer should be minimal.

The extent and character of the regional aquifer to the north is not known. Monitoring well data have not been used to construct a map of the potentiometric surface. However, the potentiometric surface should generally correspond to surface topography and rise to the north, and overall flow in the regional system would be to the south. Water in the regional system flows beneath the headwater drainages and probably has minimal influence on seeps and springs of the shallower perched systems. Water levels in observation wells in the regional aquifer in the Wasatch Plateau fluctuate seasonally, the changes lagging snowmelt and rainfall events by up to two months, and long-term decline of water levels in the wells, typically less than 3 feet per year, is attributed to long-term decreases in precipitation and to dewatering of the aquifer by mining (Coastal, 1993, PHC2-4).

Faulting has no importance in the Blackhawk Formation or Starpoint Sandstone in the western Book Cliffs. As a result, secondary permeability created by fracturing does not increase the mobility of water through the regional system here as it does in areas of the Wasatch Plateau.

Stored Mine Water System Coal mining has resulted in extensive underground mine workings in the area. Where the mine workings are below the local ground water table or where subsidence has opened fractures connecting with the perched ground water system, significant quantities of stored ground water have accumulated in the underground workings.

Abandoned mine workings that extend beneath the regional water table serve as sinks in the regional aquifer system. However, seepage into the mines is extremely slow. In the western coal reserves area, mine inflows appear to be greatest where extensive retreat mining has produced substantial subsidence. However, regardless of subsidence conditions or mining method, the overall inflow rate is low. Mine inflow monitoring by PRCC indicated inflow rates of 2.9, 12, 30 and 30 gpm for the Aberdeen, Utah Fuels No. 1, Royal, and Kenilworth mines, respectively. Similar monitoring by Castle Gate Coal Company for the No. 3 and No. 5 Mines resulted in measured inflow rates of 41 gpm (average), and 3.5 gpm for the No. 5 Mine (Table 1).

Table 1 (after TABLE 3.7-2 - Willow Creek PAP)

SUMMARY OF AVAILABLE MINE DISCHARGE/INFLOW AND GROUND WATER RECHARGE DATA

Mine	Measured Inflow gpm	Mine Area Acres	Yield/Unit Area gpm/acre	Recharge in./yr
A - Inflow to Abandoned Mines				
Aberdeen	2.9	770	0.004	0.08
Utah Fuel No. 1	12	680	0.018	0.35
Royal	30	1250	0.024	0.46
Kennilworth	30	2790	0.011	0.21
B - Inflow to Castle Gate Coal Company's Carbon County Mines				
No. 3 (11/3/82)	*48.7*	*920*	*0.053*	*1.02*
No. 3 (1/26/83)	*33.4*	*920*	*0.036*	*0.70*
No. 3 (average)	41.0	920	0.044	0.86
No. 5 (1/26/83)	3.5	232	0.015	0.29
Unweighted average			0.019	0.37
Total	119.4	6642 (10.4 mi^2)		

The total volume of ground water storage in the old mine workings in the eastern coal reserves is unknown, although it is probably substantial. There are few known instances of mine water discharge from old workings to the surface because most of the abandoned mine workings in the area have been sealed and water accumulates predominantly in down-dip workings behind the seals. Ground water inflow to the old mine workings will continue until equilibrium is established between inflow, discharge to the surface, recharge into the subsurface, and the local ground water table.

Mine inflow rates in the eastern coal reserves are expected to be similar to the western coal reserves. Measured inflow to the 10.4 square miles of existing mine workings in the Willow Creek area is approximately 120 gpm (0.3 cfs). This is the equivalent of 0.34 inch/year, well below recharge estimates (5% of annual precipitation) of 0.56 to 1.00 inch/year. Drawdown of the regional aquifer has the potential of inducing greater recharge from the surface (Freeze, 1971), but the thickness and overall low permeability of the overburden in this area would probably render such an effect undetectable. Assuming that the mine area is 19.8 square miles at the end of mine operations, i.e., old and new mine workings extending beneath approximately 90% of the proposed Willow Creek permit area, the amount of groundwater that will be intercepted annually by the mine is estimated to be 230 gpm (0.5 cfs).

Seeps and Springs

CPMC's spring and seep inventory in June 1994 and subsequent investigations have identified 3 active seeps and 12 active springs in and adjacent to the proposed Willow Creek permit area. Locations of the known springs and seeps are shown on Figure 4, and these seeps and springs are included in CPMC's ongoing monitoring program initiated in June 1994. Measured seep and spring discharges typically vary from negligible flow to approximately 5 gpm, with isolated flows of up to 10 gpm. Discharges from perched ground water systems exhibit significant seasonal variation; maximum discharge following spring snowmelt with many springs and seeps drying up during late summer and early fall.

Seeps and springs often issue at a shale-sandstone interface. There is little or no faulting in the Castle Gate/Willow Creek area. Flow along faults and fractures through the Blackhawk Formation appears minimal, and the secondary porosity that makes the Starpoint and related sandstone units good aquifers in other areas of the Wasatch Plateau and Book Cliffs is not found here in the western Book Cliffs.

Stream Seepage

Seepage studies were done in Spring Canyon creek and Willow Creek (Price and Plantz, 1987). A slight gain in flow was noted where Willow Creek crossed the North Horn Formation, but no significant increase of flow was associated with any other geologic unit. The confluence of Willow Creek with the Price River is on the Blackhawk Formation. In the creek in Spring Canyon there was a marked increase of base flow near the contact of the Starpoint Sandstone and Mancos Shale, probably from springs issuing near that contact.

Water in Mines

The coal seams that are mined are in the lower Blackhawk Formation. Ground water flow into mines in the Wasatch Plateau has been characterized as: 1) seepage from the coal seams and associated channel sandstones, 2) flow from Blackhawk channel sandstones that have been fractured by faulting and folding, or 3) flow up from the underlying barrier-beach sandstones by way of faults and fractures. Because there is little or no faulting and no folding in the Castle Gate/Willow Creek area, faults and fractures have no apparent significance in ground water flow into the mines of this area. The secondary porosity that makes the Starpoint and related sandstone units good aquifers in other areas of the Wasatch Plateau and Book Cliffs is not found here in the western Book Cliffs.

Personnel from CPMC investigated the Castlegate No. 2 Mine during 1992 - 1993. Ground water was noted at several locations, the most significant in the Kenilworth Seam workings. Advancing from west to east through the old works, investigating teams found water flowing westward along the East Mains at an estimated 2.5 gpm. This water ultimately flows north (down-dip) into old entries that are sealed at 6,230 feet elevation. Based on such available information, it can be assumed that the water level is less than 6,230 feet in this area and that the general rate of mine inflow is low.

A number of mine entries were found to be partially flooded during CPMC's 1993 inspections. Ponded, stagnant water was encountered in the East Mains in the Kenilworth Seam workings of the Castlegate No. 2 Mine, but water marks along the ribs and on timbers suggested the water level had actually dropped 6 to 12 inches. A thick oil slick was floating on the water. Stagnant water covered with an oil slick was also encountered in the C Seam works of the No. 2 Mine. Maps dating from late 1972 indicate that most water accumulations were confined to sump and adjacent areas.

Water is assumed to be originating from the underlying Kenilworth Sandstone. Analyses of a mine flow sample collected in the Kenilworth works reveal an alkaline water fairly rich in dissolved magnesium and sodium/potassium, supporting a supposition that the water flows through or is otherwise in contact with a marine unit.

Ground Water Usage

Of the four primary aquifer systems, only the alluvial/colluvial aquifer yields sufficient water to serve as a reliable source of water for beneficial use. A number of individuals, water user associations, government agencies, and corporate entities hold ground water rights for alluvial/colluvial wells in area drainages, shallow wells that intercept perched aquifers, and numerous small springs and seeps. Water rights have been filed on mine inflow or stored mine water in four mines in the area.

Actual ground water use within the hydrologic basin is primarily limited to large volume municipal and irrigation use or small volume stock watering applications. The Price River Water Improvement District extracts water for municipal use from ground water wells in Sections 23 and 24 of T. 12 S., R. 10 E. Along the Price River valley, especially near Heiner, Martin, and Helper, numerous individuals and corporations have significant water rights that are used for irrigation. Additionally, PacifiCorp owns significant water rights for water from their UGW well located in Section 35 of T12S, R9E.

In certain areas the perched ground water and stored underground mine water systems may provide water of sufficient quantity and quality for specific uses such as stock watering.

IV. BASELINE CONDITIONS OF SURFACE AND GROUND WATER QUANTITY AND QUALITY.

Surface Water

Surface water has been and is currently monitored for quantity and quality at various stations operated by the USGS and coal mine operators. Locations are shown on Figure 4 and analysis results are found in the Castle Gate Mine MRP, the Willow Creek Mine PAP, and USGS publications. Monitoring has been infrequent or irregular at some stations. For some of the surface water monitoring locations listed in Table 3.7-11 in the Willow Creek PAP, CPMC has combined analysis results from a new monitoring station with those from a nearby, older station, e.g., CPMC B-151 and CGCC/PRCC B-1. These combined data are used in the surface water quality tables in this CHIA. Both new and old locations are shown on Map 15 in the Willow Creek PAP.

Surface Water Quantity

Price River

USGS monitoring station 09313000, near the town of Heiner, has been operated for 41 years (1935-1969, 1980-1981, and 1991-1994) as part of the USGS statewide network. Scofield Reservoir regulates flow in the upper Price River, but between Scofield Reservoir and USGS station 09313000 the Price River receives significant inflows from the White River, Beaver Creek, and Willow Creek. In the general vicinity of the proposed Willow Creek permit area and upstream of the confluence with Willow Creek, Sulphur Canyon creek has been identified by CPMC as a perennial tributary to the Price River, and major intermittent drainages include Bear Canyon and Crandall Canyon. Spring Canyon, a principal drainage of the Book Cliffs west of the Price River, joins the Price River at Helper. Hardscrabble Canyon and Panther Canyon are the two major intermittent drainages tributary to the Price River between Willow Creek and Spring Canyon. Helper Canyon/Kenilworth Wash, an adjacent unnamed drainage in which the town of Kenilworth actually lies, and Cordingly and Alrad Canyons/Cardinal Wash drain south from the area proposed for mining in the Willow Creek Mine PAP and join the Price River downstream of Spring Canyon (Figure 2).

Mean annual discharge of the Price River, as measured at station 09313000 during 41 years of record, is 108 cfs (78,190 ac-ft/yr) (USGS, 1994). Relatively uniform year-round flow results from regulation at Scofield Reservoir but short term peaks occur, chiefly in August and September due to thunderstorms over one or more of the tributary drainage basins. The maximum recorded peak flow was 9,340 cfs on September 13, 1940. This flow resulted from thunderstorm activity over the drainage basins of White River and Beaver and Willow Creeks and caused considerable flood damage in Price and Helper. Minimum recorded flow was 0.40 cfs on Aug. 21, 1961.

Willow Creek

The USGS operated Station 09312800 on Willow Creek, approximately 4 miles upstream of the portals of the proposed Willow Creek Mine, from October 1962 to September 1989 as part of the statewide USGS network. Daily average flow was 9.6 cfs for this twenty-seven year period. Monthly flows were typically greatest in April through June due to snowmelt from the West Tavaputs Plateau. Lowest monthly flows were in July through September, but high daily flows frequently occurred during these same months in response to intense, local thunderstorms. Maximum measured discharge was 836 cfs on Aug. 6, 1973. Periods of no-flow were recorded during several different years, during months ranging from August through May.

USGS Station 09312900 on lower Willow Creek, near the confluence with the Price River, was monitored during water years 1980-81. Data collected at that station supplement the long-term record at upstream station 09312800. The annual mean flow of Willow Creek at station 09312900 was 17.3 cubic feet per second in water year 1980 and 4.58 cubic feet per second in water year 1981. A comparison of the two years of overlapping records from the two gaging stations indicates that with an average flow rate of 9.6 cfs (7,000 ac-ft/year) at the upper site, an average discharge of approximately 10.5 cfs (7,600 ac-ft/year) can be expected at the mouth of Willow Creek. This represents an increase of approximately 9% between the two sites.

Seven sets of base-flow measurements were made along Willow Creek downstream from station 09312800 during August 1978-August 1981. Measurements show a slight gain in flow where the stream crosses the North Horn Formation but virtually no change in flow where it crosses older rocks, including the coal-bearing Blackhawk Formation.

Spring Canyon

USGS monitoring station 09313040 was located near where Spring Canyon creek crosses the Blackhawk Formation - Mancos Shale contact just west of Helper, at an altitude of 6,110 feet, and monitored the combined flow from all the main drainages during water years 1979-1981. During the three year monitoring period at station 09313040, coal was actively mined in Spring Canyon at the Braztah (or PRCC) Mines. Most of the water produced by the mines was consumed in the mining operations, but a small, unknown quantity was intermittently discharged to Spring Canyon creek. Most of the flow in the creek originates from seeps or springs (Price and Plantz, 1989). Average daily flow data from station 09313040 indicate an average annual discharge rate of 0.296 cfs (214 acre-feet) for the three year monitoring period.

Annual mean flow at station 09313040 during the 3 years of record ranged from 0.12 cfs during water year 1979 to 0.41 cfs during water year 1981. Flow varied considerably, and short-term increases during June-November probably resulted from thunderstorms. The maximum recorded peak flow, 271 cfs on July 12, 1981, resulted from a thunderstorm. Base-flow measurements made in Spring Canyon creek upstream from station 09313040 show a marked increase in base flow beginning about 2.5 miles upstream from the station. This increase probably reflects increased spring inflow to the canyon near the contact between the Mancos Shale and the Star Point Sandstone (Price and Plantz, 1987).

Other Drainages

Three years (February 1980 through October 1983) of flow measurements collected by PRCC and CGCC on Sulphur Canyon creek indicate an average annual discharge rate of 1.11 cfs. One period of no-flow was measured when the stream was frozen.

Field measurements conducted by CPMC during 1994 at proposed Willow Creek Mine surface-water monitoring sites and surface-water flow data collected previously from intermittent and ephemeral drainages in the region suggest that surface water yields from ephemeral and intermittent tributary drainages in the proposed Willow Creek permit area

Previous mine operators initiated monitoring of flow and water quality for selected drainages in the area of the proposed Willow Creek Mine beginning in 1977; however, little or no monitoring information is available for many of the minor drainages, most of which are dry over much of the year. In June 1994 CPMC began monitoring all major and minor drainages within the proposed Willow Creek Mine permit area that showed evidence of recent flow. Surface water monitoring locations are shown on Figure 4. Limited data collected during 1994 on intermittent and ephemeral drainages do not show a pronounced seasonal variation in flow, but suggest that flow in these drainages results from precipitation events. Rapid runoff as a result short-duration high-intensity precipitation causes relatively brief, high velocity flows in the smaller drainages. Intermittent and ephemeral drainage channels generally contain flowing water only during snowmelt or precipitation events. Measured flows ranged from 0 cfs to 0.17 cfs in the intermittent and ephemeral drainages.

There are a number of very small stock-watering ponds scattered throughout the area, and each is typically associated with a spring in the headwaters of ephemeral drainages such as Panther, Deep, Buck, Mathis, and Dry Canyons. Water rights have been filed on some of the stock ponds.

Surface Water Quality

Above the Price City Price Water Supply and Treatment Plant, water in the Price River and its tributaries is classified by the Utah Division of Water Quality as:

- 1C - protected for domestic use with prior treatment,
- 2B - protected for recreational uses except swimming,
- 3A - protected for cold water species of game fish and other cold water aquatic life,
- 4 - protected for agricultural uses.

Below the water treatment plant the water is classified as:

- 2B - protected for recreational uses except swimming,
- 3C - protected for non game fish and other aquatic life, and
- 4 - protected for agricultural uses.

These classifications and the water quality standards for these waters are in Standards of Quality for Waters of the State of Utah - R317-2, Utah Administrative Code (Feb. 16, 1994). Even though Willow Creek is not protected for game fish, it is considered to be a Class 4 fishery by UDWR, which is defined as a stream with low recreational fishing potential. Cold water game fish such as rainbow trout, Yellowstone cutthroat trout, and brown trout are expected to be found. There are potentially sixty-seven species of fish in the Willow Creek drainage, although the area of the CIA provides potential habitat for only eighteen fish species.

There are a number of very small stock-watering ponds scattered throughout the area, and each is typically associated with a spring in the headwaters of ephemeral watersheds such as Panther, Deep, Buck, Mathis, and Dry Canyons. Monitoring of water in the stock ponds is done at the associated springs. Water rights have been filed on some of the stock ponds.

Objectives of surface water quality monitoring, initiated in 1977 under the Utah coal program and continued by CPMC, include; 1) definition of baseline water quality conditions; 2) identification of any seasonal variations in water quality and correlation to flow levels; and 3) identification of any mining related changes in surface water quality. Surface water monitoring has typically included measurement of flow, temperature, pH, electrical conductivity (conductance), and dissolved oxygen in the field and collection of water samples for laboratory analyses.

Chemically, surface water in the Price River is a calcium-bicarbonate type, but surface water in Willow Creek is more of a mixed type with calcium or magnesium and bicarbonate as dominant ions. Waters from ephemeral and intermittent tributaries also are calcium-bicarbonate chemical type. Springs and seeps are typically a calcium-bicarbonate type; however, some have a calcium-sulfate or sodium-bicarbonate composition.

Surface water quality varies temporally and appears to be flow dependent. Specific conductivity, TDS, and sulfate concentrations all appear to decrease during high-flow and increase during low-flow. Observed iron concentrations tend to increase with higher flows and decrease under low flow conditions. This process potentially skews the water quality data. Average concentrations of some analytes have exceeded water quality standards at one or more surface water monitoring locations.

Water quality samples have been collected at several sites (Figure 4) over various periods of time extending back to 1978. CPMC has concluded that specific conductance, TDS, and sulphate show an inverse relationship to flow in surface waters. Data from several sites indicate a direct relationship of total iron levels to flow, and concentrations of both total iron and total manganese are directly proportional to suspended solids concentrations.

Dissolved Solids (Total Dissolved Solids and Specific Conductance

Total Dissolved Solids (TDS) concentrations in the Price River (Table 2) average just over 300 mg/L and range from 190 to 1,080 mg/L. In Willow Creek (Table 3) the range is 340 to 1,200 mg/L and averages are over 500 mg/L. Samples from Sulphur Creek and Crandall Canyon (Table 2) have TDS concentrations similar to Willow Creek. TDS levels at each station in Mathis Canyon (Table 3) have fallen within narrow respective ranges, and there is a notable downstream increase in TDS between the two stations. CPMC's attributes relatively high TDS values to direct discharge of shallow perched ground water systems to surface drainages and the effect of extended dry periods that may significantly reduce stream flows, concentrate existing dissolved solids, and minimize dilution of ground water contributions. TDS measurements in Spring Canyon, average of 2,260 mg/L measured by the USGS (Table 2), are much higher than in Willow Creek or the Price River because the creek flows across the Mancos Shale before reaching the USGS sampling station. The Utah water quality standard for TDS is 1200 mg/L in Class 4 waters, the only water quality standard for TDS.

Price River conductivity measurements generally are less than those in Willow Creek. The range in the Price River is 235 to 930 μmhos/cm, while conductivity in Willow Creek ranges from 315 to 1,350 μmhos/cm. Waters in Sulphur Creek (Table 2) have specific conductance similar to Willow Creek. As with TDS, specific conductance in Mathis Canyon (Table 3) increases downstream. Specific conductance of waters sampled in Buck Canyon is similar to that of water at the upper Mathis Canyon station. The intermittent and ephemeral drainages exhibit ranges of conductivity measurements similar to Willow Creek. Spring Canyon has the highest specific conductance, averaging 2,890 μmhos/cm. There are no water quality standards for conductivity.

TDS concentrations in 24 samples collected from the Price River at USGS station 09313000 during 1979 through 1981 water years ranged from 200 to 580 mg/L and averaged 367 mg/L (Table 4). Calcium and magnesium were the dominant dissolved cations and bicarbonate was the dominant dissolved anion.

TABLE 2
Total Dissolved Solids (mg/L) and Specific Conductance (µS/cm @ 25° C) in Price Canyon and Spring Canyon drainages

Monitoring Station	Date	Average	Maximum	Minimum
Crandall Canyon				
B-25 location unknown	4/81 - 10/83 (*one sample only)	* *	*410 mg/L *514 µS	*410 mg/L *514 µS
B-26 middle Crandall Canyon (no specific conductance measured)	4/81 - 10/83	774 mg/L	1,480 mg/L	395 mg/L
Price River, just above confluence with Sulphur Creek				
CGCC/PRCC B-20	02/80 - 10/83	314 mg/L 380 µS	880 mg/L 575 µS	189 mg/L 235 µS
Sulphur Creek				
CPMC BN-221 (CGCC/PRCC B-19)	6/78 - 3/95	562 mg/L 667 µS	840 mg/L 1,350 µS	348 mg/L 328 µS
Price River, just below (above) Bear Canyon				
CPMC B-6 (CGCC/PRCC B-6)	6/78 - 3/95	319 mg/L 435 µS	910 mg/L 710 µS	190 mg/L 250 µS
Price River, just above confluence with Willow Creek (at confluence with Barn Canyon)				
CPMC B-5 (CGCC/PRCC B-5)	6/78 - 3/95	329 mg/L 447 µS	1,080 mg/L 795 µS	198 mg/L 253 µS
Price River, at Heiner				
USGS 09313000	10/79 - 9/81	367 mg/L 579 µS	580 mg/L 930 µS	200 mg/L 330 µS
Spring Canyon, below Sowbelly Gulch				
USGS 09313040	10/79 - 9/81	2,260 mg/L 2,890 µS	2,600 mg/L 3,200 µS	481 mg/L 770 µS

Specific Conductance measured in the field

Dissolved-solids concentrations in 37 streamflow samples taken from Spring Canyon creek at station 09313040 ranged from 481 to 2,600 mg/L and averaged 2,260 mg/L. Magnesium and sulfate were the dominant cation and anion. Strontium was the dominant trace element, with concentrations as large as 1,400 µgm/l (Price and Plantz, 1987).

CPMC's monitoring station B-151 is at or near the same location as USGS gaging station 09312800, near the head of Willow Creek canyon. USGS station 09312800 was monitored for flow and Specific Conductance only. TDS measurements for Willow Creek are summarized in Table 3. Data in Table 3 do not indicate significant variation in dissolved solids over the monitored section of Willow Creek, although it must be remembered that these data are temporally scattered and possibly determined by a variety of methods.

USGS station 09312900, on Willow Creek near PacifiCorp's Castle Gate Generating Plant, was operated continuously during water years 1980 and 1981. Chemical analyses of 24 streamflow samples are summarized in

Table 4. TDS concentrations ranged from 350 to 810 mg/L and averaged 591 mg/L. Magnesium and bicarbonate were the dominant cation and anion in most of the samples regardless of the total dissolved-solids concentrations. Strontium was found in concentrations as large as 1,100 μg/L (Price and Plantz, 1987).

TABLE 3
Total Dissolved Solids (mg/L) and Specific Conductance (μS/cm @ 25° C) in Willow Creek drainage

Monitoring Station	Date	Average	Maximum	Minimum
Buck Canyon, just below Deep Canyon - Buck Canyon confluence				
CPMC B-253 (no TDS determination)	7/94 - 9/94	530 μS	548 μS	513 μS
Willow Creek, near the head of the canyon, at the confluence with Buck Canyon, just below Emma Park				
USGS 09312800 (no TDS determination)	1969 - 1989 *1989 only	*924 μS	*990 μS	*850 μS
CPMC B-151 (CGCC/PRCC B-1)	6/78 - 3/95	579 mg/L 707 μS	1,198 mg/L 1,150 μS	365 mg/L 365 μS
Mathis Canyon				
CPMC B-353 upper Mathis Canyon	7/94 - 3/95	272 mg/L 528 μS	296 mg/L 573 μS	248 mg/L 517 μS
CPMC B-211 at Willow Creek confluence	6/94 - 3/95	426 mg/L 760 μS	444 mg/L 910 μS	408 mg/L 704 μS
Willow Creek, between Mathis and Hell Canyons				
CGCC/PRCC B-1 (see CPMC B-151)	-	-	-	-
Willow Creek, between Dinosaur and Castle Canyons				
CGCC/PRCC B-2	6/78 - 3/95	562 mg/L 667 μS	840 mg/L 1,350 μS	348 mg/L 328 μS
Lower Willow Creek, near PacifiCorp's Castle Gate generating plant				
USGS 09312900	10/79 - 9/81	591 mg/L 920 μS	810 mg/L 1,280 μS	350 mg/L 450 μS
CPMC BN-3 (CGCC/PRCC B-3)	2/80 - 3/95	536 mg/L 703 μS	720 mg/L 1,152 μS	345 mg/L 315 μS

Specific Conductance measured in the field

The impact of the Mancos Shale on water quality is very evident in the samples collected at USGS Station 09313040 in Spring Canyon (Table 2). However, even though the Price River begins flowing on the Mancos Shale approximately one mile upstream of the USGS monitoring station at Heiner, TDS and specific conductance appear little affected at that location because of the larger discharge of the Price River.

Sulfate

There is no Utah water quality standard for sulfate. Sulfate concentrations appear to be slightly elevated in Willow Creek with respect to other area surface drainages. The sulfate concentration in Willow Creek generally ranges from 150 to 230 mg/L. Measured concentrations in the Price River tend to range from 20 to 100 mg/L. The limited data for intermittent and ephemeral tributaries suggests sulfate concentrations range from 20 to 140 mg/L. Natural sulfur springs have been identified in Sulphur Canyon, along Willow Creek canyon, and in a number of other area drainages. Hydrogen sulfide gas (H_2S) has been documented in area wells. In essentially all cases, elevated sulfate values in surface waters can be correlated to nearby natural sources.

Iron and Manganese

The State standard for dissolved iron is 1000 mg/L maximum in all Class 3 waters and there is no standard for dissolved manganese. Secondary drinking water (SDW) standards for total iron and manganese are, respectively, 0.3 mg/L and 0.05 mg/L.

Total iron concentrations in surface water appear to be similar in the Price River and Willow Creek (Tables 5 and 6). Concentration in the Price River range from less than 0.5 to approximately 25 mg/L. Concentrations in Willow Creek are slightly higher, with maximum measured concentrations of approximately 36 mg/L. The limited data for the intermittent and ephemeral drainages show total iron concentrations typically ranging from 0.03 to 0.3 mg/L. Antone Creek appears to be an exception, with measured concentrations ranging from 0.04 to 2.71 mg/L.

It appears that these total iron concentrations are due to natural processes because both the downgradient and upgradient Willow Creek monitoring stations have similar total iron concentrations. Many lithologic units in the area show visible evidence of iron cementation, and considering the direct correlation between elevated iron levels and high levels of suspended solids it is reasonable to assume the observed elevated iron levels can be correlated to natural sources and the processes of weathering, oxidation, erosion, and sediment transport.

Other Metals or Ions

The standard for copper (12 μg/L four day average or 18 μg/L one hour average) for Class 3 waters has been exceeded at B-1 and B-3 in Willow Creek and at B-151 in Willow Creek, and copper and zinc (110 μg/L four day average or 120 μg/L one hour average) standards has been exceeded in Crandall Canyon at B-26.

Chemical analyses of 24 streamflow samples collected at USGS station 09312900 on Willow Creek during the 1980 and 1981 water years are summarized in Table 4. Magnesium and bicarbonate were the dominant cation and anion in most of the samples. Trace elements were found in concentrations that did not exceed Utah Water Quality or USEPA standards, although strontium was found in concentrations as high as 1,100 μg/L (Price and Plantz, 1987).

Dissolved solids concentrations in 37 streamflow samples taken from Spring Canyon creek at station 09313040 ranged from 481 to 2,600 mg/L and averaged 2,260 mg/L. Magnesium and sulfate were the dominant cation and anion. Strontium was the dominant trace element, with concentrations as large as 1,400 μg/L. Of the trace elements analyzed, lead and selenium were found in concentrations that exceeded both USEPA and Utah Water Quality criteria: both the maximum and mean concentrations of selenium exceeded the USEPA criterion of 10 μg/L (Price and Plantz, 1987). Chromium was found in concentrations up to 30 μg/L, exceeding the Utah Water Quality standard of 16 μg/L for Class 3 type waters.

TABLE 4

Summary of chemical analyses of streamflow in the Price River, Willow Creek, and Spring Canyon creek Water years 1980-81 (Price and Plantz, 1987)
USGS stations 09313000, 09312900, and 09313040
[< indicates actual value is smaller than the detectable limit value shown]

Properties and constituents	Price River 09313000 No. of analyses	Price River 09313000 Mean	Price River 09313000 Minimum-maximum	Willow Creek 09312900 No. of analyses	Willow Creek 09312900 Mean	Willow Creek 09312900 Minimum-maximum	Spring Canyon creek 09313040 No. of analyses	Spring Canyon creek 09313040 Mean	Spring Canyon creek 09313040 Minimum-maximum
Streamflow (cubic feet per second)	25	124	6.8-918	25	12.1	0.35-173	37	1.4	0.05-38.0
Water temperature (degrees Celsius)	25	9.4	.0-20.0	25	10.0	.0-27.0	37	11.4	4.0-26.0
Specific conductance (microsiemens per centimeter at 25° Celsius)	25	579	330-930	25	920	450-1,280	37	2,890	770-3,200
pH (units)	25	--	8.1-9.0	25	--	8.1-8.8	37	--	7.8-8.4
Sodium-absorption ratio	25	.7	.3-1.0	25	1.8	.9-2.0	37	1.6	.3-5.5
mg/L	mg/L			mg/L			mg/L		
Dissolved solids, sum of constituents	24	367	200-580	24	591	350-810	37	2,260	481-2,600
oxygen, dissolved (O_2)	25	9.8	7.5-13.1	25	9.3	6.4-12.0	37	9.0	7.0-11.2
Carbon dioxide, dissolved (CO_2)	24	1.4	.5-3.9	24	1.9	.7-4.7	36	4.9	1.9-7.7
Alkalinity ($CaCO_3$)	24	217	140-290	24	284	210-350	36	382	100-430
Bicarbonate (HCO_3) [1]	24	250	170-400	24	331	230-420	36	468	120-520
Carbonate (CO_3) [1]	24	5.8	.0-22	24	7.3	.0-16	36	--	.0-2
Nitrogen, dissolved (N)	8	.70	.20-.94	8	.45	.15-.74	7	7.1	3.1-8.5
Nitrogen, organic dissolved (N)	4	.35	.11-.52	4	.37	.11-.63	8	.71	.40-1.4
Nitrogen, ammonia dissolved (N)	4	--	<.01-.050	4	--	<.01-.030	8	--	<.01-.190
Nitrogen, nitrite dissolved (N)	4	--	<.010	4	--	.01	3	--	<.01-.020
Nitrogen, nitrate dissolved (N)	4	--	<.05-.50	4	--	<.05-.06	7	5.9	5.0-6.8
Nitrogen, nitrite + nitrate (N)	8	.27	.03-.50	8	--	<.01-.27	12	6.0	1.5-7.8
Phosphorus, dissolved (P)	4	.075	.010-.270	4	--	<.01-.240	4	--	<.01-.220
Phosphorus, ortho, dissolved (P)	4	--	<.001-.010	4	--	.001-.010	8	--	<.001-.030
Carbon, organic dissolved *	8	7.0	2.2-15	8	6.2	1.5-14	8	8.7	2.6-28
Hardness, (as $CaCO_3$)	25	255	160-390	25	342	180-500	37	1,440	370-2,100
Hardness, (as noncarbonate, ($CaCO_3$)	24	44.8	0-130	24	65	.0-150	36	1,190	270-1,700
Calcium, dissolved (Ca)	25	57	36-85	25	56	32.0-82	37	202	79-230
Magnesium, dissolved (Mg)	25	27	16-47	25	49	20-72	37	258	42-380
Sodium, dissolved (Na)	25	27.7	7.9-56.0	25	77	30-100	37	143	15-360
Potassium, dissolved (K)	25	1.9	.9-3.2	25	2.7	1.7-3.6	37	17.5	1.7-21
Chloride, dissolved (Cl)	25	17.2	5.8-41.0	25	26.1	9.8-45	37	84.9	36-120
Sulfate, dissolved (SO_4)	25	88	28-200	25	194	70-300	37	1,300	200-1,500
Fluoride, dissolved (F)	17	.2	.1-.3	17	.26	.20-0.50	21	.4	.3-.5
Silica, dissolved (SIO^2)	25	8.1	3.3-14.0	25	12.2	6.8-15	37	11.4	5.0-16
µg/L	µg/L			µg/L			µg/L		
Arsenic, dissolved (As)	6	1.7	1.0-3.0	6	2.2	2.0-3.0	11	--	<1-3
Barium, dissolved (Ba)	2	--	<100-200	12	150	100-200	2	150	100-200
Boron, dissolved (B)	17	136	20-610	17	97	60-180	21	--	<10-700
Cadmium, dissolved (Cd)	2	--	<1-2	2	--	<1-1	3	--	<1-1
Chromium, dissolved (Cr)	6	--	<10-20	5	--	<10-10	7	--	<10-30
Copper, dissolved (Cu)	2	3.0	2.0-4.0	2	2.5	2-3	3	5	2-10
Iron, dissolved (Fe)	17	--	<10-30	17	--	<10-80	21	34	10-60
Lead, dissolved (Pb)	6	--	<1-5.0	6	--	<1-2	11	--	<1-81
Lithium, dissolved (Li)	6	--	<10-30	6	28	20-40	10	173	150-190
Manganese, dissolved (Mn)	17	11.2	3.0-30	17	12.2	2-30	21	23	10-50
mercury, dissolved (Hg)	2	--	<.1	2	--	<.1	3	--	<1-1
Nickel, dissolved (Ni)	2	8	2-14	2	--	<1	3	2.7	1-6
Selenium, dissolved (Se)	6	--	<1-3.0	6	1.7	1.0-3.0	11	15	3-21
Strontium, dissolved (Sr)	6	455	300-630	6	717	350-1,100	10	1,200	1,000-1,400
Zinc, dissolved (Zn)	6	--	<3-20	6	4.2	3.0-7.0	11	20	10-40
Phenols	7	--	<1-10	8	7.2	1.0-33	8	--	<1-14

[1] Fixed-end-point determined by titration in the field.

CHIA - WILLOW CREEK AND ADJACENT AREAS

TABLE 5
Iron and Manganese (in mg/L) in Price Canyon and Spring Canyon drainages

Monitoring Station	Date	Iron - total		Iron - diss.		Manganese -total		Manganese - diss.	
		Avg.	Range	Avg.	Range	Avg.	Range	Avg.	Range
Crandall Canyon									
B-25 location unknown	4/81 - 10/83 (*one sample only)	*	*4.16	-	-	*	*0.16	-	-
B-26 middle Crandall Canyon	4/81 - 10/83	17.7	0.36 - 42.5	-	-	0.26	0.005 - 0.78	-	-
Price River, just above confluence with Sulphur Creek									
CGCC/PRCC B-20	02/80 - 10/83	3.8	0.21 - 25.8	0.07	0.02 - 0.13	0.18	<0.001 - 1.2	-	-
Sulphur Creek									
CPMC BN-221 (CGCC/PRCC B-19)	6/78 - 3/95	0.055	0.015 - 4.25	0.38	<0.02 - 1.04	0.04	0.004 - 0.16	<0.01	<0.01
Price River, just below (above) Bear Canyon									
CPMC B-6 (CGCC/PRCC B-6)	6/78 - 3/95	2.73	0.01 - 25.3	0.023	<0.01 - 0.04	0.145	0.006 - 1.22	0.009	<0.005 - 0.02
Price River, just above confluence with Willow Creek (at confluence with Barn Canyon)									
CPMC B-5 (CGCC/PRCC B-5)	6/78 - 3/95	2.9	0.09 - 30.5	0.16	<0.01 - 0.68	0.15	0.016 - 1.3	0.009	<0.005 - 1.3
Price River, at Heiner									
USGS 09313000	10/79 - 9/81	-	-	0.034	<0.010 - 0.030	-	-	0.0112	0.003 - 0.030
Spring Canyon, below Sowbelly Gulch									
USGS 09313040	10/79 - 9/81	-	-	0.034	0.010 - 0.060	-	-	0.023	0.010 - 0.050

TABLE 6
Iron and Manganese (in mg/L) in Willow Creek drainage

Monitoring Station	Date	Iron - total		Iron - diss.		Manganese -total		Manganese - diss.	
		Avg.	Range	Avg.	Range	Avg.	Range	Avg.	Range
Buck Canyon, just below Deep Canyon - Buck Canyon confluence									
CPMC B-253	7/94 - 9/94	-	-	-	-	-	-	-	-
Willow Creek, near the head of the canyon, at the confluence with Buck Canyon, just below Emma Park									
USGS 09312800	1969 - 1983	-	-	-	-	-	-	-	-
CPMC B-151 (CGCC/PRCC B-1)	6/78 - 3/95	55.2	0.04 - 1,230	0.016	<0.01 - 0.04	0.033	<0.01 - 0.085	0.21	<0.01 - 1.7
Mathis Canyon, at the confluence with Willow Creek									
CPMC B-253 upper Mathis Canyon	7/94 - 3/95	0.185	0.08 - 0.29	0.015	<0.02 - 0.02	0.013	<0.01 - 0.02	0.008	<0.01 - 0.01
CPMC B-211 at Willow Creek confluence	6/94 - 3/95	0.055	0.03 - 0.08	<0.02	<0.02	<0.01	<0.01	<0.01	<0.01
Willow Creek, between Mathis and Hell Canyons									
CGCC/PRCC B-1	-	-	-	-	-	-	-	-	-
Willow Creek, between Dinosaur and Castle Canyons									
CGCC/PRCC B-2	6/78 - 3/95	6.7	0.06-33.8	0.02	0.02 - 0.02	0.25	0.002 - 1.7	-	-
Lower Willow Creek, near PacifiCorp's Castle Gate generating plant									
USGS 09312900	10/79 - 9/81	-	-	-	<0.010 - 0.080	-	-	0.0122	0.002-0.030
CPMC BN-3 (CGCC/PRCC B-3)	2/80 - 3/95	6.9	0.09-35.6	0.15	<0.01 -0.69	0.194	<0.01-0.02	0.01	<0.01-0.02

pH

Extreme pH values measured in the field range from 6.4 to 9.6 but averages range from 7.9 to 8.6, indicating overall neutral to moderately alkaline conditions. Utah water quality standards are 6.5 to 9.0 for all classes of water. High pH values are relatively common in the arid western United States and reflect the alkaline geochemistry of the dominant stratigraphic units. When pH values for stations above and below existing mine disturbance areas are compared, available monitoring data indicates no significant variance and thus no significant impact from these activities (Tables 7 and 8).

TABLE 7
pH (measured in the field) in Price Canyon and Spring Canyon drainages

Monitoring Station	Date	Average	Maximum	Minimum
Crandall Canyon				
B-25 location unknown	4/81 - 10/83 (*one sample only)	*	*8.2	*8.2
B-26 middle Crandall Canyon	4/81 - 10/83	8.4	9.2	7.7
Price River, just above confluence with Sulphur Creek				
CGCC/PRCC B-20	02/80 - 10/83	8.1	9.5	6.7
Sulphur Creek				
CPMC BN-221 (CGCC/PRCC B-19)	6/78 - 3/95	8	9.2	6.4
Price River, just below (above) Bear Canyon				
CPMC B-6 (CGCC/PRCC B-6)	6/78 - 3/95	8.1	9.5	7.1
Price River, just above confluence with Willow Creek (at confluence with Barn Canyon)				
CPMC B-5 (CGCC/PRCC B-5)	6/78 - 3/95	8.2	9.6	7
Price River, at Heiner				
USGS 09313000	10/79 - 9/81	-	9.0	8.1
Spring Canyon, below Sowbelly Gulch				
USGS 09313040	10/79 - 9/81	-	8.4	7.8

Where both acidity and alkalinity have been determined, alkalinity is typically at least one order of magnitude greater, and often as much as four to five orders greater, than acidity.

TABLE 8
pH (measured in the field) in Willow Creek Canyon

Monitoring Station	Date	Average	Maximum	Minimum
Buck Canyon, just below Deep Canyon - Buck Canyon confluence				
CPMC B-253	7/94 - 9/94	8.36	8.44	8.3
Willow Creek, near the head of the canyon, at the confluence with Buck Canyon, just below Emma Park				
USGS 09312800	1969 - 1983	-	-	-
CPMC B-151 (CGCC/PRCC B-1)	6/78 - 3/95	8.1	9.4	6.8
Mathis Canyon, at the confluence with Willow Creek				
CPMC-353 upper Mathis Canyon	7/94 - 3/95	8.6	9	8.3
CPMC B-211 at Willow Creek confluence	6/94 - 3/95	8.4	8.6	7.9
Willow Creek, between Mathis and Hell Canyons				
CGCC/PRCC B-1	-	-	-	-
Willow Creek, between Dinosaur and Castle Canyons				
CGCC/PRCC B-2	6/78 - 3/95	8.2	9.2	7.5
Lower Willow Creek, near PacifiCorp's Castle Gate generating plant				
USGS 09312900	10/79 - 9/81	-	8.8	8.1
CPMC BN-3 (CGCC/PRCC B-3)	2/80 - 3/95	-	-	7.1

Phenols

Utah water quality standard for phenols is 0.01 mg/L for all Class 3 waters. At USGS station 09312900 on Willow Creek, eight of the twenty-four water samples collected from October 1979 to September 1981 were analyzed for phenols and measurable concentrations (0.001 mg/L or greater) were found in all eight. Average concentration was 0.0072 mg/L and 0.033 mg/L was the maximum. During the same period, phenol concentrations in seven samples from USGS station 09313000 on the Price River ranged from below detection to 0.01 mg/L (Price and Plantz, 1987).

Elevated phenol levels were found by CPMC in at least one sample from each of the following: B-1, B-2, and B-3 in Willow Creek; B-5, B-6, B-20, and B-21 in the Price River; B-26 in Crandall Canyon; and B-19 in Sulphur Canyon. The average phenol concentration exceeded the 0.01 mg/L criterion at B-1, B-3, B-5, B-6, B-19, and B-20. These high phenol levels cannot be associated with any known disturbance or mining activities. Because phenols are a common product of natural oxidation and in-situ combustion of coal, the observed elevated phenol levels may be due to natural processes.

Solids

Considering the topography and climate of the area, high Total Suspended Solids (TSS) values are to be expected during spring runoff and following major thunderstorms. Extremely steep natural slopes and channel gradients combine with short duration, high-intensity flows from snowmelt and thunderstorms to produce significant surface erosion and sediment transport. Weathering and mass wasting produce colluvial deposits on lower slopes and in drainages, with runoff then mobilizing and transporting the smaller size colluvial particles. There are water quality standards for turbidity but not for suspended solids.

Analyses of stream-bottom sediments at USGS station 09312900 indicate that those sediments consist of as much as 2.3 percent coal, upstream coal storage or mine spoils being the most likely sources for this coal. Two benthic invertebrate samples were collected during water year 1980 and five phytoplankton samples were collected during water year 1981. Benthic invertebrates had fairly good diversity indicating an apparently unpolluted streambottom environment. The phytoplankton showed considerable variation (Price and Plantz, 1987).

Concentrations of suspended sediment in 21 samples collected at USGS station 09313000 ranged from 58 to 1,520 mg/L during water year 1980 and from 21 to 4,270 mg/L during water year 1981 (Table 9). Instantaneous suspended-sediment loads ranged from 2.7 to 3,770 tons/day during water year 1980 and from 0.59 to 1,090 tons/day during water year 1981. Coal was as much as 8 percent of the stream-bottom sediments sampled at the station. Two samples of benthic invertebrates collected during the 1980 water year had good diversity indicating an apparently unpolluted stream bottom at the station. Five samples of phytoplankton collected during water year 1981 showed a uniform distribution of green algae with good diversity (Price and Plantz, 1987).

TABLE 9
Total suspended solids (in mg/L) in Price Canyon and Spring Canyon drainages

Monitoring Station	Date	Average	Maximum	Minimum
Crandall Canyon				
B-25 location unknown	4/81 - 10/83 (*one sample only)	*	*475	*475
B-26 middle Crandall Canyon	4/81 - 10/83	367	736	54
Price River, just above confluence with Sulphur Creek				
CGCC/PRCC B-20	02/80 - 10/83	314	880	189
Sulphur Creek				
CPMC BN-221 (CGCC/PRCC B-19)	6/78 - 3/95	27.9	215	<0.1
Price River, just below (above) Bear Canyon				
CPMC B-6 (CGCC/PRCC B-6)	6/78 - 3/95	200	1,633	0.5
Price River, just above confluence with Willow Creek				
CPMC B-5 (CGCC/PRCC B-5)	6/78 - 3/95	188.6	1,604	<1
Price River, at Heiner				
USGS 09313000	10/79 - 9/81	-	4,270	21
Spring Canyon, below Sowbelly Gulch				
USGS 09313040	10/79 - 9/81	-	99,800	3

At station USGS 09312900 during the 1980 and 1981 water years, suspended-sediment concentrations in 20 samples ranged from 2 to 4,820 mg/L. Calculated instantaneous suspended-sediment loads ranged from 0.02 to 902 tons/day in water year 1980 and from 0.01 to 547 tons/day in water year 1981 (Price and Plantz, 1987).

Suspended-sediment concentrations in 25 samples collected at USGS station 09313040 during water years 1980 and 1981 ranged from 3 mg/L on December 6, 1981 to 99,800 mg/L on July 12, 1981. Instantaneous suspended-sediment loads ranged from 0.05 to 0.07 tons/day during water year 1979, 0.01 to 0.43 tons/day in water year 1980, and from less than 0.01 to 10,200 tons/day in water year 1981. No determinations were made of the composition of suspended sediment in samples collected during the monitoring period. On August 29, 1969, however, Spring Canyon creek, while flowing at a rate of 0.6 cfs, had a suspended-sediment concentration of 2,260 mg/L and about 90 percent of the suspended sediment was coal. Price and Plantz (1987) identified coal spills, mine spoils, and coal-loading facilities associated with the earlier mines in the canyon as the most likely sources of the coal particles (Price and Plantz, 1987).

Measured TSS concentrations in the Willow Creek drainage ranged from 1 to 4,310 mg/L (Table 10).

TABLE 10
Total Suspended Solids (in mg/L) in Willow Creek drainage

Monitoring Station	Date	Average	Maximum	Minimum
Buck Canyon, just below Deep Canyon - Buck Canyon confluence				
CPMC B-253	7/94 - 9/94	-	-	-
Willow Creek, near the head of the canyon, at the confluence with Buck Canyon, just below Emma Park				
USGS 09312800	1969 - 1983	-	-	-
CPMC B-151 (CGCC/PRCC B-1)	6/78 - 3/95	334	2,622	1
Mathis Canyon, at the confluence with Willow Creek				
CPMC B-353 upper Mathis Canyon	7/94 - 3/95	<2	-	-
CPMC B-211 at Willow Creek confluence	6/94 - 3/95	2	-	-
Willow Creek, between Mathis and Hell Canyons				
CGCC/PRCC B-1	-	-	-	-
Willow Creek, between Dinosaur and Castle Canyons				
CGCC/PRCC B-2	6/78 - 3/95	436	4,310	1
Lower Willow Creek, near PacifiCorp's Castle Gate generating plant				
USGS 09312900	10/79 - 9/81	-	4,820	2
CPMC BN-3 (CGCC/PRCC B-3)	2/80 - 3/95	465	4,105	<2

Nitrogen and Phosphorus

Nitrate is the only form of nitrogen consistently monitored. Nitrate is considered an indicator of pollution in concentrations greater than 4 mg/L (as N) in class 1C, 2A, 3A, 3B, and 3C waters. The average nitrate level found by USGS monitoring in Spring Canyon was 5.9 mg/L (Tables 4 and 11). When analysis has been done for nitrite, concentrations have generally been below detection limits: the highest concentration reported was 0.04 mg/L in a sample from Sulphur Canyon. Dissolved nitrogen, dissolved organic nitrogen, and dissolved ammonia were determined by the USGS for the three stations listed in Table 4, and the highest concentrations for all three forms of nitrogen were found in Spring Canyon.

Phosphate (as phosphorus) concentrations in excess of 0.05 mg/L, considered an indicator of pollution for Class 2A, 2B, 3A and 3B waters, have been found in Willow Creek (Table 12) at B-2, BN-3 (B-3), and B-151 (B-1); in the Price River at B-5, B-6, B-20, and B-21; in Crandall Canyon at B-25 and B-26; and in Sulphur Canyon at BN-221 (Table 11).

TABLE 11
Nitrogen and Phosphorus (in mg/L) in Price Canyon and Spring Canyon drainages

Monitoring Station	Date	Nitrate (as N)		Phosphate (as P)	
		Average	Range	Average	Range
Crandall Canyon					
B-25 location unknown	4/81 - 10/83 (*one sample only)	*	*0.06	*	*0.13
B-26 middle Crandall Canyon	4/81 - 10/83	-	-	0.12	0.01 - 0.30
Price River, just above confluence with Sulphur Creek					
CGCC/PRCC B-20	02/80 - 10/83	0.118	<0.01 - 0.56	0.09	0.002 - 0.29
Sulphur Creek					
CPMC BN-221 (CGCC/PRCC B-19)	6/78 - 3/95	0.05	<0.01 - 0.51	0.053	<0.001 - 0.23
Price River, just below (above) Bear Canyon					
CPMC B-6 (CGCC/PRCC B-6)	6/78 - 3/95	0.14	<0.01 - 0.63	0.08	<0.01 - 0.35
Price River, just above confluence with Willow Creek (at confluence with Barn Canyon)					
CPMC B-5 (CGCC/PRCC B-5)	6/78 - 3/95	0.158	<0.01 - 0.64	0.09	<0.01 - 0.55
Price River, at Heiner					
USGS 09313000	10/79 - 9/81	-	<0.05 - 0-.50	-	<0.001 - 0.010
Spring Canyon, below Sowbelly Gulch					
USGS 09313040	10/79 - 9/81	5.9	5.0 - 6.8	-	<0.001 - 0.030

TABLE 12
Nitrogen and Phosphorus (in mg/L) in Willow Creek drainage

Monitoring Station	Date	Nitrate (as N)		Phosphate (as P)	
		Average	Range	Average	Range
Buck Canyon, just below Deep Canyon - Buck Canyon confluence					
CPMC B-263	7/94 - 9/94	-	-	-	-
Willow Creek, near the head of the canyon, at the confluence with Buck Canyon, just below Emma Park					
USGS 09312800	1969 - 1983	-	-	-	-
CPMC B-151 (CGCC/PRCC B-1)	6/78 - 3/95	0.08	<0.01 - 0.58	0.1	0.005 - 0.55
Mathis Canyon, at the confluence with Willow Creek					
CPMC B-353 upper Mathis Canyon	7/94 - 3/95	<0.02	-	<0.005	-
CPMC B-211 at Willow Creek confluence	6/94 - 3/95	0.04	0.02 - 0.06	<0.005	-
Willow Creek, between Mathis and Hell Canyons					
CGCC/PRCC B-1	-	-	-	-	-
Willow Creek, between Dinosaur and Castle Canyons					
CGCC/PRCC B-2	6/78 - 3/95	0.09	<0.01 - 1.02	0.23	<0.01 - 3.26
Lower Willow Creek, near PacifiCorp's Castle Gate generating plant					
USGS 09312900	10/79 - 9/81	-	<0.05 - 0.06	-	0.001 - 0.010
CPMC BN-3 (CGCC/PRCC B-3)	2/80 - 3/95	0.08	<0.01 - 0.63	0.10	0.01 - 0.39

Oil and Grease

Analysis for oil and grease was done regularly by mine operators up until approximately 1994, when Freon needed to do the extraction became unavailable. CPMC has continued monitoring for oil and grease by simple visual inspection.

As can be seen in Tables 13A and 13B, there have been high levels of oil and grease in most of the area streams at some time. There is no water quality standard for oil and grease, but a limit of 10 mg/L oil and grease is common in UPDES permits. A 10 mg/L limit does not protect fish and benthic organisms from soluble oils such as those used in longwall hydraulic systems, and UDWR has recommended soluble oils be limited to 1 mg/L (Darrell H. Nish, Acting Director UDWR, letter dated April 17, 1989 to Dianne R. Nielsen, Director UDOGM).

TABLE 13A
Oil and Grease (in mg/L) in Price Canyon and Spring Canyon drainages

Monitoring Station	Date	Average	Maximum	Minimum
Crandall Canyon				
B-25 location unknown	4/81 - 10/83 (*one sample only)	*	*0.8	*0.8
B-26 middle Crandall Canyon	4/81 - 10/83	1.5	3.8	<0.2
Price River, just above confluence with Sulphur Creek				
CGCC/PRCC B-20	02/80 - 10/83	4.4	57	<0.1
Sulphur Creek				
CPMC BN-221 (CGCC/PRCC B-19)	6/78 - 3/95	2.27	24.2	<0.01
Price River, just below (above) Bear Canyon				
CPMC B-6 (CGCC/PRCC B-6)	6/78 - 3/95	2.5	28.4	<0.1
Price River, just above confluence with Willow Creek (at confluence with and Barn Canyon)				
CPMC B-5 (CGCC/PRCC B-5)	6/78 - 3/95	3.02	40	<1
Price River, at Heiner				
USGS 09313000	10/79 - 9/81	-	-	-
Spring Canyon, below Sowbelly Gulch				
USGS 09313040	10/79 - 9/81	-	-	-

TABLE 13B
Oil and grease (in mg/L) in Willow Creek drainage

Monitoring Station	Date	Average	Maximum	Minimum
Buck Canyon, just below Deep Canyon - Buck Canyon confluence				
CPMC B-253	7/94 - 9/94	-	-	-
Willow Creek, near the head of the canyon, at the confluence with Buck Canyon, just below Emma Park				
USGS 09312800	1969 - 1983	-	-	-
CPMC B-151 (CGCC/PRCC B-1)	6/78 - 3/95	1	7.6	<0.1
Mathis Canyon, at the confluence with Willow Creek				
CPMC B-353 upper Mathis Canyon	7/94 - 3/95	2	2	2
CPMC B-211 at Willow Creek confluence	6/94 - 3/95	<1	<1	<1
Willow Creek, between Mathis and Hell Canyons				
CGCC/PRCC B-1	-	-	-	-
Willow Creek, between Dinosaur and Castle Canyons				
CGCC/PRCC B-2	6/78 - 3/95	0.92	6.4	<0.1
Lower Willow Creek, near PacifiCorp's Castle Gate generating plant				
USGS 09312900	10/79 - 9/81	-	-	-
CPMC BN-3 (CGCC/PRCC B-3)	2/80 - 3/95	1.6	10.6	<0.1

Temperature

Water temperatures in streams fluctuate greatly, especially when low flows and turbulence act to rapidly equilibrate water temperatures with air temperatures. In the CIA temperatures as high as 35°C (95°F) have been reported in Willow Creek and 32°C (90°F) in Sulphur Canyon, and maximum temperatures of 20 to 25°C (68 to 77°F) are common (Tables 14 and 15). The reported minimum is typically 0°C (32°F) . Average temperatures reported increase consistently downstream for the Price River (7.8, 8.1, 8.7, and 9.4 °C) but not for Willow Creek. The maximum allowable temperature for Class 3A and 3C waters is 27°C (80°F) and maximum allowable temperature change due to discharge from a point source is 4°C (7.2°F).

TABLE 14
Temperature (in °C) in Price Canyon and Spring Canyon drainages

Monitoring Station	Date	Average	Maximum	Minimum
Crandall Canyon				
B-25 location unknown	4/81 - 10/83 (*one sample only)	*	*23	*23
B-26 middle Crandall Canyon	4/81 - 10/83	6.4	11	2
Price River, just above confluence with Sulphur Creek				
CGCC/PRCC B-20	02/80 - 10/83	7.8	20	0
Sulphur Creek				
CPMC BN-221 (CGCC/PRCC B-19)	6/78 - 3/95	13.3	32	-4
Price River, just below (above) Bear Canyon				
CPMC B-6 (CGCC/PRCC B-6)	6/78 - 3/95	8.1	9.5	7.1
Price River, just above confluence with Willow Creek (at confluence with Barn Canyon)				
CPMC B-5 (CGCC/PRCC B-5)	6/78 - 3/95	8.7	20.4	0.2
Price River, at Heiner				
USGS 09313000	10/79 - 9/81	9.4	20	0
Spring Canyon, below Sowbelly Gulch				
USGS 09313040	10/79 - 9/81	11.4	26	4

TABLE 15
Temperature (in °C) in Willow Creek drainage

Monitoring Station	Date	Average	Maximum	Minimum
Buck Canyon, just below Deep Canyon - Buck Canyon confluence				
CPMC B-263	7/94 - 9/94	11.05	21.1	1
Willow Creek, near the head of the canyon, at the confluence with Buck Canyon, just below Emma Park				
USGS 09312800	1969 - 1983	-	-	-
CPMC B-151 (CGCC/PRCC B-1)	6/78 - 3/95	9.5	23	0
Mathis Canyon, at the confluence with Willow Creek				
CPMC B-353 upper Mathis Canyon	7/94 - 3/95	14	21	9.3
CPMC B-211 at Willow Creek confluence	6/94 - 3/95	13.8	25.1	1.5
Willow Creek, between Mathis and Hell Canyons				
CGCC/PRCC B-1	-	-	-	-
Willow Creek, between Dinosaur and Castle Canyons				
CGCC/PRCC B-2	6/78 - 3/95	8.7	22	0
Lower Willow Creek, near PacifiCorp's Castle Gate generating plant				
USGS 09312900	10/79 - 9/81	10	27	0
CPMC BN-3 (CGCC/PRCC B-3)	2/80 - 3/95	14.6	35	-1

Fish, Invertebrates, and Aquatic Habitat (see Willow Creek PAP)

Analyses of stream-bottom sediments from USGS station 09312900 on lower Willow Creek indicate that those sediments consist of as much as 2.3 percent coal, upstream coal storage or mine spoils being the most likely sources for this coal. Two benthic invertebrate samples were collected during water year 1980 and five phytoplankton samples were collected during water year 1981. Benthic invertebrates had fairly good diversity indicating an apparently unpolluted stream bottom environment. The phytoplankton showed considerable variation (Price and Plantz, 1987).

Benthic invertebrates collected at USGS station 09313040 in Spring Canyon during the 1979 and 1980 water years showed only fair diversity. Five samples of phytoplankton during the 1981 water year showed a fairly uniform dispersion of green algae; however, blue-green algae were also well represented in the samples (Price and Plantz, 1987).

Discussions between CPMC and Utah Division of Wildlife Resources (UDWR) resulted in an initial decision to conduct aquatic habitat and biology studies during the fall of 1994 and spring/summer of 1995. However, because of drought conditions in 1994, only preliminary site-specific surveys were conducted in October 1994 to provide basic permitting data on habitat and biological communities. A fish population survey was done 28-29 June 1995, which involved two passes through each of the six sections. Results of both surveys are summarized in Table 16.

Site-specific aquatic studies were conducted on October 10 through 12, 1994 to provide habitat, benthic macroinvertebrate, and fisheries information for Willow Creek. Six sampling locations were used to characterize aquatic biota, while seven locations were examined for aquatic habitat. Information on stream depth, width, velocity, pool/riffle ratio, pool and riffle lengths, and substrate was collected or recorded during site-specific habitat surveys. The benthic macroinvertebrate survey involved the collection of two replicate samples at each location using a Surber sampler. A backpack electroshocker was used to sample fish populations within a segment of Willow Creek approximately 300 feet long at each sampling location.

Game Fish The permit area provides potential habitat for eighteen fish species. Willow Creek is considered to be a Class 4 fishery by UDWR, which is defined as a stream with low recreational fishing potential. Game fish species expected to occur in Willow Creek include rainbow trout, Yellowstone cutthroat trout, and brown trout. Only one rainbow trout, 8.5 inches in length, was collected at WC-3 during the electroshocking survey conducted on October 12, 1994. Results of the 1994 fish sampling efforts are summarized by Table 16. CPMC's discussions with UDWR indicated that trout species likely occur in relatively low numbers in Willow Creek. Because spawning conditions are poor in this section of Willow Creek, the primary use by trout species is considered to be as a migration route. The sporadic occurrence of trout in lower Willow Creek is primarily related to seasonal spawning migrations and habitat limitations. Rainbow and Yellowstone cutthroat trout are suspected to move from the Price River into Willow Creek and other tributaries during their spring spawning periods (usually early May through June for Yellowstone cutthroat and mid-March through June for rainbow). Brown trout move into tributary streams in October. After spawning, adult fish migrate back to the Price River.

TABLE 16
(Adapted from TABLES 3.3-2 and 3.3-2A - Willow Creek PAP)

NUMBER OF FISH COLLECTED IN WILLOW CREEK, OCTOBER 12, 1994							
Common Name	Scientific Name	WC-1R	WC-2	WC-3	WC-4	WC-5	WC-6
Mountain sucker	*Catostomus platyrhynchus*	26	18	28	14	13	5
Speckled dace	*Rhinichthys osculus*	30	12	17	13	12	9
Rainbow trout	*Oncorhynchus mykiss*	0	0	1	0	0	0
Total		76	30	46	27	25	14

FISH POPULATION SURVEY - WILLOW CREEK, JUNE 28-29, 1995							
Common Name	**Scientific Name**	**WC-1R**	**WC-2**	**WC-3**	**WC-4**	**WC-5**	**WC-6**
Mountain sucker	*Catostomus platyrhynchus*	50	29	15	21	9	9
Speckled dace	*Rhinichthys osculus*	40	8	13	18	33	34
Rainbow trout	*Oncorhynchus mykiss*	0	0	1	0	3	0
Bullhead Sucker	*Catostomus discobolus*	4	1	0	3	0	0
Redside Shiner	*Richardsonius balteatus*	0	0	0	1	1	5
Weighted Total	(see Willow Creek PAP)	78	40	29	41	43	41

Trout in Willow Creek also may originate from upstream sources. Prior to 1994, fingerling rainbow trout were stocked in the upper portions of Willow Creek, although the UDWR has indicated that stocking of rainbow trout in Willow Creek may be discontinued. During high flow periods, trout may be washed downstream into the lower portions of Willow Creek.

The Price River is also considered a Class 4 fishery. Game fish populations in the Price River downstream of the Willow Creek confluence are comprised of both warmwater and coldwater species. Game fish species include brown trout, Yellowstone cutthroat trout, rainbow trout, and channel catfish. Population studies on a section of the Price River upstream of the Willow Creek confluence, completed in 1981 for UDWR, indicated a trout density of 64 ± 6 for the sampled reaches. This population estimate would also be representative of the Price River from the Willow Creek confluence downstream to Helper. Fingerling rainbow trout and brown trout are stocked in the Price River by UDWR. Yellowstone cutthroat trout occur in small tributaries to the Price River but are no longer stocked in the Price River drainage.

Non-game Fish Non-game fish species in Willow Creek consist of speckled dace and mountain sucker. The results of the October 1994 survey indicated that species abundance varied from 5 to 30 individuals/300-ft section at the six sampling locations as shown by Table 16. During years with higher flows, other minnow species that are found in the region may occur in Willow Creek.

Non-game fish species in the Price River downstream of the Willow Creek confluence are similar to regional lists. UDWR surveys have collected flannelmouth sucker, mountain sucker, bluehead sucker, mottled sculpin, carp, Utah chub, longnose dace, speckled dace, and redside shiner.

Macroinvertebrates CPMC's October 1994 macroinvertebrate sampling in Willow Creek revealed relatively low macroinvertebrate densities, number of taxa, and species diversities at all locations. Total densities ranged from 12.5 individuals/ft^2 at WC-5 to 53 individuals/ft^2 at WC-1R. The lowest number of macroinvertebrate taxa was found at two of the downstream locations (7 at WC-4 and 9 at WC-5). The other four locations supported 13 to 20 taxa, which is considered a low number of taxa in a Surber sample. The EPT Index (the number of Ephemeroptera [mayflies], Plecoptera [stoneflies], and Trichoptera [caddisflies] taxa) and the EPT abundances (total EPT individuals/ft^2) also were low at all locations. Macroinvertebrate densities and the EPT Index were slightly higher at the upstream locations (WC-1R, WC-2, and WC-3) compared to the downstream locations (WC-4, WC-5, and WC-6). The relatively low densities and few taxa found for these indicator groups indicate water quality and habitat conditions were low. The drought conditions in 1994 likely contributed to the low macroinvertebrate productivity.

CPMC calculated Shannon species diversity indices for each sampling location, which provided an indication of the density distribution among the various taxa. Diversity values less than 2 generally indicate a possible stressed biological community, as shown by the dominance of relatively few, tolerant taxa. In the Willow Creek study, the upstream locations (WC-1R, WC-2, and WC-3) showed mean diversities ranging from 1.78 to 2.31. In contrast, diversity indices at the downstream locations (WC-4, WC-5, and WC-6) were lower, with values from 1.15 to 1.66.

The most abundant taxon at five of the six sampling locations was the mayfly, *Tricorythodes*, which comprised about 18 to 45 percent of the total macroinvertebrate densities. This particular mayfly is tolerant of silt conditions. Other dominant taxa (greater than 5 percent of the total densities at a location) included Tanypodinae chironomid midges, oligochaetes (worms), caddisflies, mayflies, Elmidae beetles, and dragonflies. The midges, oligochaetes, and beetles also are able to tolerate silt conditions.

Aquatic Habitat The overall quality of aquatic habitat in this section of Willow Creek is limited due to erosion, siltation, and relatively low flows during most months, except during spring runoff and after large thunderstorm events. Based on a habitat characterization survey conducted on October 10 and 11, 1994, a thick silt/clay layer was evident on the rock surfaces in both pools and riffles. The dominant substrate sizes in pools were clay, silt, and rubble (cobble), and riffle substrates were dominated by clay, silt, rubble, and boulder sized materials. Riffles represented the major type of habitat at most of the habitat characterization locations. Due to the low flow (approximately 1.5 cubic ft/sec) at the time of the survey, depths and velocities were low in both pools and riffles. Maximum depths in most pools ranged from about 1 to 2 ft. Pool habitat was created by numerous large boulders at scattered locations throughout the stream. A series of five pools was found immediately downstream of an existing road culvert (approximately 400 ft upstream of location H-5), which collectively represent the largest quantity of deep, pool habitat along Willow Creek in the proposed mining area. Total length of the pools was approximately 100 ft, with maximum depths of approximately 1 to 3.5 ft. A series of concrete steps that were constructed by UDWR serve as a fish ladder.

The quality of cover for fish communities is limited due to relatively low flows during most months. During the October 1994 survey, limited amounts of cover were provided by rubble and boulder substrates, overhanging riparian vegetation (mainly small willows and grasses), and instream debris such as tree limbs. Undercut banks were generally absent throughout this section of Willow Creek. The accumulation of boulders at several locations in the stream create vertical drops of about 1 to 2 ft, which would restrict upstream fish movement during low flow periods. However, increased depths during spring runoff and after storm events would allow upstream fish movement. The quantity of substrate cover for fish also would increase in response to increased water volumes during high flow periods. The presence of the thick silt/clay layer on the stream substrates limited aquatic vegetation growth and the development of a productive and diverse macroinvertebrate community.

Habitat attributes in Willow Creek were rated as low quality, with little submerged aquatic vegetation, cover ranging from about 10 to 25 percent of the total area surveyed, stream widths ranging from about 2 to 6 feet, and average velocities ranging from 0.25 to 0.49 ft/sec. The low abundance and diversity of fish and macroinvertebrate communities in Willow Creek are a reflection of the limiting habitat conditions. Resident fish populations are comprised of non-game species such as speckled dace and mountain sucker. Although these data suggested slight improvements in habitat and water quality conditions in the upper portion of the study area, the overall quality rating would still be considered low.

Aquatic habitat in the lower portion of Willow Creek is limited due to the silt/clay layer on the rock surfaces, the small size of the stream, relatively low flows during most months, and limited amounts of cover provided by substrates, instream debris, and overhanging riparian vegetation. Increased surface flows in average and wet years would provide some additional cover and habitat for fish and macroinvertebrate communities, although cover is still expected to be limited.

Threatened, Endangered, and Sensitive Species Potential habitat for two Federal candidate (Category 2) fish species, roundtail chub and leatherside chub exists in Willow Creek. Although these species historically occurred in the Price River and its tributaries, CPMC cites UDWR information that neither species has been recently identified or observed in Willow Creek. Leatherside chub has been collected recently in the Price River upstream of the Willow Creek confluence.

Seven Federally listed or candidate fish species occur or could potentially occur in the Price River below the Willow Creek confluence. Potential habitat exists for three Federal candidate Category 2 species: roundtail chub, leatherside chub, and flannelmouth sucker.

Ground Water

Ground Water Quality

The major ion composition of ground water is variable, but ground water in the Willow Creek Mine area is typically a weak calcium sulfate or sodium sulfate chemical type. Ground water in the western coal reserve area, including mine discharge and inflow, is typically a weak calcium sulfate chemical type, with a sodium bicarbonate type in one well.

Available water quality information is summarized in Tables 17 through 19. Locations of seeps and springs sampled are shown on Figure 4. Samples are rarely taken during the first quarter because of snow cover at most locations.

Ground water quality is dependent on the source of recharge, flow path, nature of the strata through which the water flows, and discharge mechanism. Generally, water quality for alluvial/colluvial ground water sources is very similar to that of surface water in the associated drainages and reflects the close interaction between the two systems. On the other hand, the quality of ground water from perched, stored mine water, and the regional aquifer ground water systems reflects some degradation relative to surface water sources due to contact with and dissolution of minerals and salts in the geologic sequence. Interception of ground water by abandoned mine workings may reduce further downward percolation and resulting degradation of water within the regional ground water aquifer.

Of the ground water encountered within the mines, water quality data are available only from cross-cut 3 of the Royal Mine between March 1985 and April 1992. Water from this location was slightly alkaline and pH averaged 8.2 and ranged from 7.4 to 8.6 with no apparent seasonal variation. Calcium/magnesium and bicarbonate were the dominant ions. TDS averaged 647 mg/L and ranged from 275 to 1060 mg/L. Total iron averaged 2.42 mg/L and ranged from less than 0.02 to 12.70 mg/L, and total manganese averaged 0.09 and ranged from 0.01 to 0.46 mg/L. Both total iron and manganese appear directly proportional to suspended solids concentrations; however, suspended solids were probably the result of sampling error rather than solids in the ground water. No seasonal variations were evident.

A relatively short flow path between the recharge area and discharge point for most perched ground water results in limited water quality degradation. Generally, TDS concentrations are less than 500 mg/ in springs issuing from the Flagstaff or North Horn Formations but 800 to 1000 mg/L in springs issuing from the Price River Formation. For both stored mine water and the regional ground water aquifer water quality is generally lower the deeper in the geologic sequence the water is found, the downward percolating water dissolving anions and cations from all units, and salts from shale members in particular: TDS concentrations in deeper portions of the regional aquifer such as the Mancos Shale frequently exceed 3000 mg/L. Data from the Castle Gate mines indicate that TDS values for the regional ground water aquifer and stored mine water in the western coal reserve area are within the same range, and there is no indication that mine inflow, water accumulation, and long-term ground water storage in abandoned mine workings results in any significant ground water quality degradation.

There is some potential that ground water and surface water quality in the permit and adjacent areas may be affected by a coalbed methane degassification project located north of the proposed Willow Creek Mine and adjacent areas. The Cockrell Oil Company is extracting water from approximately 25 coalbed methane wells in the Blackhawk Formation, primarily from the Aberdeen sandstone, to desorb methane from the coal matrix. Methane is removed from the water, the water stream is treated to reduce TDS and volume, and the remaining water is injected into the Price River Formation. Injected water may increase the discharge rate from springs and seeps downgradient of the degassification project, quality of spring and seep discharges may be degraded by the injected concentrate, and quality of water in the Price River may eventually be affected. Both the extraction and injection wells are outside areas covered by Willow Creek Mine MRP maps, but water injected into the Price River Formation could extend further than projected by the environmental analysis for the degassification project and encroach into the Willow Creek permit area. Water quality impacts could be locally significant within the Willow Creek permit area and the resulting degradation of ground water quality due to the coalbed methane project could be misinterpreted as being related to Willow Creek mining activities.

There are a number of very small stock-watering ponds scattered throughout the area, and they are typically associated with a spring in the headwaters of ephemeral watersheds such as Panther, Deep, Buck, Mathis, and Dry Canyons. The stock ponds and associated springs are monitored at sites B41, B71, B261, B341 and B342. The water quality of these springs is summarized in Tables 17 through 19. Water rights have been filed on some of the stock ponds.

Total Dissolved Solids (TDS)

Monitored springs and seeps issuing from strata above the Blackhawk Formation have average TDS values in the range of 300 to 400 mg/L. Concentrations go from a low of 255 mg/L to a high of 422 mg/L (Table 17A).

TDS levels recorded for the two monitored springs issuing from the Blackhawk Formation (Table 17A) range from 1,090 mg/L to 4,104 mg/L. Although there are only two springs that are monitored and only one sample from one of those springs, TDS concentrations in ground water at the top of the Blackhawk appear to be less than in ground water lower in the formation. TDS concentrations in the six wells or drill holes that have been monitored (Table 17B) fall between 850 mg/L to 2,450 mg/L, although four of the wells have had only one sample each. TDS concentrations in the mines (Table 17B) range from a high of 4,420 mg/L in the #3 Mine to a low of 700 in the Royal Mine. Average TDS for the #3 Mine, 2,910 mg/L, is roughly 2000 mg/L higher than average TDS in the Royal Mine.

Average TDS values for the single Mancos Shale spring (Table 17A) are 1,025 mg/L (1980-1983) and 2,824 mg/L (1993-94), which is less than for the Blackhawk in the #3 Mine and the spring in Panther Canyon (B-71).

TABLE 17A
Total Dissolved Solids (mg/L) and Specific Conductance (μS/cm @ 25° C) in springs and seeps

Monitoring Station	Date	Average	Maximum	Minimum
Flagstaff Limestone				
unnamed drainage				
B-241 T12S, R10E, nw nw Sec. 24 Possibly Historic Robb Spring	6/94 - 3/95 (*one sample only)	* *	*340 mg/L *688 μS	*340 mg/L *688 μS
Deep Canyon				
B-261 T12S, R10E, ne se Sec. 26 Pace Spring	6/94 - 3/95 (*one sample only)	* *	*290 mg/L * 630 μS	*290 mg/L * 630 μS
North Horn Formation				
Deep Canyon				
B-262 T12S, R10E, ne ne Sec 26 unnamed spring	7/94 - 3/95	358 mg/L 714(?) μS	418 mg/L 845 μS	320 mg/L 645 μS
Mathis Canyon				
B-32 T12S, R10E ne ne Sec 27 unnamed spring	6/80 - 10/83	313 mg/L 453 μS	352 mg/L 529 μS	288 mg/L 270 μS
B-33 T12S, R10E sw nw Sec 27 unnamed spring	5/78 - 6/79	338 mg/L - μS	396 mg/L - μS	255 mg/L - μS
B-341 T12S, R10E, se ne Sec. 24 Mathis Spring	6/94 - 3/95	409 mg/L 802 μS	422 mg/L 848 μS	398 mg/L 748 μS
B-342 T12S, R10E, ne ne Sec. 34 unnamed spring	6/94 - 3/95	356 mg/L 796μS	360 mg/L 842 μS	352 mg/L 750 μS
B-351 T12S, R10E, sw se sec. 35 unnamed spring	6/94 - 3/95 (*one sample only)	* *	*294 mg/L *643 μS	*294 mg/L *643 μS
Price River Formation				
Dry Canyon				
B-41 T13S, R10E, se se Sec. 4 Jack Spring	6/94 - 3/95	328 mg/L 469 μS	338 mg/L 469 μS	333 mg/L 469 μS
Castlegate Sandstone				
* No springs or seeps *				

Specific Conductivity measured in the field

TABLE 17A (cont)
Total Dissolved Solids (mg/L) and Specific Conductance (μS/cm @ 25° C) in springs and seeps

Blackhawk Formation				
Willow Creek canyon (upper Blackhawk)				
B-321 T12S, R10E, nw nw Sec. 32 Willow Creek/Sulphur Spring	9/94 - 3/95 (*one sample only)	* *	*1,090 mg/L *1,563 μS	*1,090 mg/L *1,563 μS
Panther Canyon (middle Blackhawk)				
B-71 T13S, R10E, ne ne Sec. 7 unnamed spring	6/94 - 3/95	3,827 mg/L 2,855 μS	4,104 mg/L 4,230 μS	3,430 mg/L 416 μS
Starpoint Sandstone				
* no springs or seeps *				
Mancos Shale				
unnamed drainage near town of Kenilworth				
MC-207 T13S, R10E, ne sw Sec. 16 near Kenilworth adit	6/80 - 8/83	1,025 mg/L 1,675 μS	1,679 mg/L 1,820 μS	1,120 mg/L 1,350 μS
B-161 (same location as MC-207)	6/94 - 3/95	2,824 mg/L 2,833 μS	2,890 mg/L 4,090 μS	2,732 mg/L 410 μS

Specific Conductivity measured in the field

Except for B-71, B-331, and B-161 (Table 17A), observed electrical conductivity (EC) values generally correlate well with TDS values, with EC to TDS ratios roughly between 1:2 to 1:1.

TABLE 17B
Total Dissolved Solids (mg/L) and Specific Conductance (µS/cm @ 25° C) in monitoring wells and mines

Blackhawk Formation				
Panther Canyon				
B-51 Aberdeen Ss. - TD unknown T13S, R10E, se sw Sec. 5 Panther Canyon well	6/94 - 3/95 (*one sample only)	* *	*2,450 mg/L *3,020 µS	*2,450 mg/L *3,020 µS
Alrad Canyon				
B-121 Aberdeen Ss. - TD unknown T13S, R10E, sw nw Sec. 12 Alrad Canyon well	9/94 - 3/95 (*one sample only)	* *	*1,270 mg/L *1,226 µS	*1,270 mg/L *1,226 µS
Dry Canyon				
B-331 Aberdeen Ss - TD 1,330 T12S, R10E, ne nw Sec. 33	10/94 - 3/95 (*one sample only)	* *	*2.070 mg/L *1,226 µS	*2.070 mg/L *1,226 µS
B-331A Blackhawk Fm. - TD 660 (twin to B-331)	10/94 - 3/95 (*one sample only)	* *	*1,300 mg/L *3,350 µS	*1,300 mg/L *3,350 µS
Sowbelly Gulch				
MC-205 TD unknown T13S, R9E, se ne Sec 5	6/80 - 8/83	1,109 mg/L 1,724 µS	1,320 mg/L 1,990 µS	856 mg/L 1,496 µS
Bear Canyon				
MC-206 TD unknown T13S, R9E, ne se Sec 33	6/80 - 8/83	1,363 mg/L 1,962 µS	1,652 mg/L 2,550 µS	1,160 mg/L 1,500 µS
Mine #3 Discharge				
B-001	7/78 - ?	2,910 mg/L 5,150 µS	4,420 mg/L *	1,400 mg/L *
Royal Mine				
BM-25 (bottom of mine)	6/77 - 4/78	1,081 mg/L 1,646 µS	1,350 mg/L 2,060 µS	906 mg/L 1,390 µS
BM-26	6/77 - 4/78	861 mg/L 1,313 µS	1,300 mg/L 1,990 µS	700 mg/L 1,060 µS
BM-27	6/77 - 4/78	1,082 mg/L 1,510 µS	1,200 mg/L 1,790 µS	964 mg/L 1,060 µS
BM-28	6/77 - 4/78	1,007 mg/L 1,539 µS	1,240 mg/L 1,850 µS	896 mg/L 1,380 µS

Specific Conductivity measured in the field

Iron and Manganese

Total iron concentrations (Table 18A) are small in springs and seeps, generally below 1 mg/L and with many below the lower detection limit of 0.02 mg/L. Spring water from the marine Mancos Shale had the highest total iron concentrations, ranging from 0.112 to 4.55 mg/L, but there is no clear indication that total iron concentrations are higher in older strata.

Dissolved iron concentrations are also low, most being below the lower detection limit of 0.02 mg/L. The highest value, 0.16 mg/L, was found in water from the middle Blackhawk Formation at the spring in Panther Canyon.

In the one reported analysis of water from Sulphur (Willow Creek) Spring in the upper Blackhawk Formation total manganese was 0.78 mg/L and dissolved manganese was 0.81 mg/L. Most samples from other sites have concentrations for both forms of manganese that are below detection limits.

Total iron concentrations are considerably higher in water samples from the monitoring wells and mines (Table 18B) than from the springs. The two wells in the western coal tract have higher total iron values than those in the eastern tract, although there has been less sampling in the three eastern tract wells. Average total iron was 37.2 mg/L in well MC-205 in Sowbelly Gulch with a high of 70.6 mg/L. Well MC-206 in Bear Canyon averaged 11.8 mg/L dissolved iron, and the high was 23.6 mg/L. However, manganese concentrations appear to be higher in the eastern tract wells, where total manganese was 0.16 to 1.08 mg/L and dissolved manganese less than 0.005 to 0.86 mg/L, than in the western tract, where the range of values was 0.02 to 0.88 mg/L total manganese and dissolved manganese has been below detection limits. Total iron and total manganese concentrations in the mine water samples were similar to those in the monitoring wells except the maxima were not as high. Mine waters have not been analyzed for dissolved iron or dissolved manganese.

Many lithologic units in the area show visible evidence of iron cementation, and it is reasonable to assume the observed elevated iron levels can be correlated to natural sources and the processes of weathering, oxidation, erosion, and sediment transport. However, the higher levels of iron in the drill holes and mines may indicate contamination from drilling or coal production operations.

The Utah standard for dissolved iron is 1000 mg/L maximum in all Class 3 waters, but there is no standard for dissolved manganese. Secondary drinking water (SDW) standards for total iron and manganese are, respectively, 0.3 mg/L and 0.05 mg/L.

TABLE 18A
Iron and Manganese (in mg/L) in springs and seeps

Monitoring Station	Date	Iron - total		Iron - diss.		Manganese - total		Manganese - diss.	
		Avg.	Range	Avg.	Range	Avg.	Range	Avg.	Range
Flagstaff Limestone									
unnamed drainage									
B-241 T12S, R10E, nw nw Sec. 24 Historic Robb Spring (?)	6/94 - 3/95 (*one sample only)	*	*0.73	*	*<0.02	*	*<0.01	*	*<0.01
Deep Canyon									
B-261 T12S, R10E, ne se Sec. 26 Pace Spring	6/94 - 3/95 (*one sample only)	*	*0.07	*	<0.02	*	*0.22	*	*0.19
North Horn Formation									
Deep Canyon									
B-262 T12S, R10E, ne ne Sec 26. (?) unnamed spring	7/94 - 3/95	0.41	<0.02 - 1.14	0.17	<0.02 - 0.03	<0.01	<0.01 - <0.01	<0.01	<0.01 - <0.01
Mathis Canyon									
B-32 T12S, R10E ne ne Sec 27 unnamed spring	6/80 - 10/83	0.57	0.04 - 1.2	-	-	0.02	<0.01 - 0.03	-	-
B-33 T12S, R10E sw nw Sec 27 unnamed spring	5/78 - 6/79	0.3	0.006 - 1.2	-	-	-	-	-	-
B-341 T12S, R10E, se ne Sec. 24 Mathis Spring	6/94 - 3/95	<0.02	<0.02 - <0.02	<0.02	<0.02 - <0.02	<0.01	<0.01 - <0.01	<0.01	<0.01 - <0.01
B-342 T12S, R10E, ne ne Sec. 34 unnamed spring	6/94 - 3/95	0.09	0.07 - 0.11	<0.02	,0.02 - <0.02	0.013	<0.01 - 0.02	<0.01	<0.01 - <0.01
B-352 T12S, R10E, sw se Sec. 35 unnamed spring	6/94 - 3/95 (*one sample only)	*	*0.63	*	*<0.02	*	*<0.03	*	*<0.01

CHIA - WILLOW CREEK AND ADJACENT AREAS

TABLE 18A (cont)
Iron and Manganese (in mg/L) in springs and seeps

Price River Formation									
Dry Canyon									
B-41 T13S, R10E, se se Sec. 4 Jack Spring	6/94 - 3/95	0.21	0.1 - 0.32	<0.02	<0.02 - <0.02	<0.01	<0.01 - <0.01	<0.01	<0.01 - <0.01
Castlegate Sandstone									
* No springs or seeps *									
Blackhawk Formation									
Willow Creek canyon (upper Blackhawk)									
B-321 T12S, R10E, nw nw Sec. 32 Willow Creek/Sulphur Spring	9/94 - 3/95 (*one sample only)	*	*0.08	*	*0.02	*	*0.78	*	*0.81
Panther Canyon (middle Blackhawk)									
B-71 T13S, R10E, ne ne Sec. 7 unnamed spring	6/94 - 3/95	0.07	0.04 - 0.14	0.11	<0.01 - 0.16	<0.01	<0.01 - <0.01	<0.01	<0.01 - <0.01
Starpoint Sandstone									
* no springs or seeps *									
Mancos Shale									
unnamed drainage near town of Kenilworth									
MC-207 T13S, R10E, ne sw Sec. 16 near Kenilworth adit	6/80 - 8/83	1.4	0.12 - 4.55	-	0.08	0.033	0.012 - 0.14	-	<0.0002
B-161 (same location as MC-207)	6/94 - 3/95	0.21	0.07 - 0.3	0.04	<0.01 - 0.06	<0.01	<0.01 - ,0.01	<0.01	,0.01 - <0.01

TABLE 18B
Iron and Manganese (in mg/L) in monitoring wells and mines

Monitoring Station	Date	Iron - total		Iron - diss.		Manganese -total		Manganese - diss.	
		Avg.	Range	Avg.	Range	Avg.	Range	Avg.	Range
Blackhawk Formation									
Panther Canyon									
B-51- Panther Canyon well Aberdeen Ss. - TD unknown T13S, R10E, se sw Sec. 5	10/94 - 3/95 (*one sample only)	•	*15.7	•	*0.39	•	*0.89	•	*0.86
Alrad Canyon									
B-121 - Alrad Canyon well Aberdeen Ss. - TD unknown T13S, R10E, sw nw Sec. 12	10/94 - 3/95 (*one sample only)	•	9.9	•	*<0.01	•	*0.16	•	*<0.005
Dry Canyon									
B-331 Aberdeen Ss. - TD 1,330 T12S, R10E, ne nw Sec. 33	10/94 - 3/95 (*one sample only)	•	*6.49	•	<0.01	•	*0.28	•	*0.23
B-331A Blackhawk Fm. - TD 660 (twin to B-331)	10/94 - 3/93 (*one sample only)	•	*0.17	•	*<0.02	•	*1.08	•	*0.44
Sowbelly Gulch									
MC-205 T13S, R9E, se ne Sec 5	6/80 - 8/83	37.2	1.5 - 70.6	-	-	0.25	0.17 - 0.3	-	-
Bear Canyon									
MC-206 T13S, R9E, ne se Sec 33	6/80 - 8/831	4.6	0.13 - 26.4	11.8	0.09 - 23.6	0.38	0.02 - 0.88	-	<0.0002
Mine #3 Discharge									
B-001	7/78 - ?	0.292	0.091 - 0.565	-	-	-	-	-	-
Royal Mine									
BM-25 (bottom of mine)	6/77 - 4/78	1.076	0.072 - 3.42	-	-	0.073	0.023 - 0.218	-	-
BM-26	6/77 - 4/78	6	0.051 - 16.43	-	-	0.13	0.021 - 0.227	-	-
BM-27	6/77 - 4/78	0.32	0.149 - 0.409	-	-	0.06	0.004 - 0.156	-	-
BM-28	6/77 - 4/78	2.92	0.436 - 4.39	-	-	0.28	0.039 - 0.395	-	-

Other Metals and Ions

The Utah water quality standard for copper, 18 $\mu g/L$ one hour average (12 $\mu g/L$ four day average) for Class 3 waters has been exceeded in samples from drill holes MC-205, MC-206 and springs MC-207, B-32, and B-33. The standard for zinc in Class 3 waters, 120 $\mu g/L$ one hour average (110 $\mu g/L$ four day average) has been exceeded in samples from drill holes MC-205 and MC-206; spring MC-207; and two locations in the Royal Mine.

Additionally, samples from drill holes MC-205 and MC-206 have exceeded Utah Water Quality Class 3 standards, and in some cases Class 1 and 4 standards also, for cadmium, chromium, and silver. Standards for arsenic and lead were exceeded in some samples from drill hole MC-206 and spring MC-207, and for fluoride in MC-206.

The presence of so many contaminants in samples from drill holes MC-205 and MC-206 may indicate contamination from drilling and well completion procedures rather than ground water conditions.

In one sample from spring B-71 and in several samples from BM-25 at the bottom of the Royal Mine, selenium concentrations exceeded the 10 $\mu g/L$ Utah Water Quality criterion.

Oil and Grease

There is no water quality standard for oil and grease, but a limit of 10 mg/L oil and grease is common in UPDES permits. A 10 mg/L limit does not protect fish and benthic organisms from soluble oils such as those used in longwall hydraulic systems, and UDWR has recommended soluble oils be limited to 1 mg/L (Darrell H. Nish, Acting Director UDWR, letter dated April 17, 1989 to Dianne R. Nielsen, Director UDOGM).

Analysis for oil and grease was done regularly by mine operators up until approximately 1994, when Freon needed to do the extraction became unavailable. CPMC has continued monitoring for oil and grease by simple visual inspection.

Oil and grease analysis results for ground water are summarized in Tables 19A and 19B. Concentrations ranging from 1 to 6 mg/L have been recorded in waters from monitoring wells B-51, B-121, B331, and B-331A. These values are at or slightly above the detection limit and may be a reflection of naturally occurring petroleum in the sedimentary sequence or of contamination from constituents used during the construction and installation of the monitoring wells. Drill holes MC-205 and MC-206 in the western tract had maximum oil and grease concentrations of 1.4 and 52.2 mg/L, respectively. Oil and grease concentrations of 107.2 and 25,000 mg/L were recorded for spring MC-207 in 1981. During CPMC's 1993 inspections of the old mine workings, oil slicks floating on water were observed in the No. 2 Mine. Water samples collected from the Royal Mine in 1977 to 1978 found oil and grease concentrations to range from below detection to 4,070 mg/L. Oil and grease in springs and seeps (other than the 1981 MC-207 samples) ranges from below detection to 23 mg/L. No oil and grease has been detected in B-41, B-241, B-261, B-321, B-342, and B-351, but some of these springs have been sampled only once.

TABLE 19A
Oil and Grease in ground water in springs seeps

Monitoring Station	Date	Average	Maximum	Minimum
Flagstaff Limestone				
unnamed drainage				
B-241 T12S, R10E, nw nw Sec. 24 Possibly Historic Robb Spring	6/94 - 3/95 (*one sample only)	*<1	*	*
Deep Canyon				
B-261 T12S, R10E, ne se Sec. 26 Pace Spring	6/94 - 3/95 (*one sample only)	*<1	*	*
North Horn Formation				
Deep Canyon				
B-262 T12S, R10E, ne ne Sec 26 unnamed spring	7/94 - 3/95	<1	15	5.3
Mathis Canyon				
B-32 T12S, R10E ne ne Sec 27 unnamed spring	6/80 - 10/83	<0.1	3.2	1.4
B-33 T12S, R10E sw nw Sec 27 unnamed spring	5/78 - 6/79	<1	4.6	1.6
B-341 T12S, R10E, se ne Sec. 24 Mathis Spring	6/94 - 3/95	<1	23	8
B-342 T12S, R10E, ne ne Sec. 34 unnamed spring	6/94 - 3/95	<1	<1	<1
B-351 T12S, R10E, sw se sec. 35 unnamed spring	6/94 - 3/95 (*one sample only)	*<1	*	*
Price River Formation				
Dry Canyon				
B-41 T13S, R10E, se se Sec. 4 Jack Spring	6/94 - 3/95	<1	<1	<1
Castlegate Sandstone				
* No springs or seeps *				

TABLE 19A (cont)
Oil and Grease in ground water in springs and seeps

Blackhawk Formation				
Willow Creek canyon (upper Blackhawk)				
B-321 T12S, R10E, nw nw Sec. 32 Willow Creek/Sulphur Spring	9/94 - 3/95 (*one sample only)	*<1	*	*
Panther Canyon (middle Blackhawk)				
B-71 T13S, R10E, ne ne Sec. 7 unnamed spring	6/94 - 3/95	<1	4	1.67
Starpoint Sandstone				
* no springs or seeps *				
Mancos Shale				
unnamed drainage near town of Kenilworth				
MC-207 T13S, R10E, ne sw Sec. 16 near Kenilworth adit	6/80 - 8/83	107.2	25,000	12,554
B-161 (same location as MC-207)	6/94 - 3/95	<1	17	6

TABLE 19B
Oil and Grease in monitoring wells and mines

Blackhawk Formation				
Panther Canyon				
B-51 Aberdeen Ss. - TD unknown T13S, R10E, se sw Sec. 5 Panther Canyon well	6/94 - 3/95 (*one sample only)	*2	*	*
Alrad Canyon				
B-121 Aberdeen Ss. - TD unknown T13S, R10E, sw nw Sec. 12 Alrad Canyon well	9/94 - 3/95 (*one sample only)	*3	*	*
Dry Canyon				
B-331 Aberdeen Ss - TD 1,330 T12S, R10E, ne nw Sec. 33	10/94 - 3/95 (*one sample only)	*6	*	*
B-331A Blackhawk Fm. - TD 660 (twin to B-331)	10/94 - 3/95 (*one sample only)	*1	*	*
Sowbelly Gulch				
MC-205 T13S, R9E, se ne Sec 5	6/80 - 8/83	<0.2	1.4	0.83
Bear Canyon				
MC-206 T13S, R9E, ne se Sec 33	6/80 - 8/83	<0.1	52.2	16.9
Mine #3 Discharge				
B-001	7/78 - ?	<1	-	-
Royal Mine				
BM-25 (bottom of mine)	6/77 - 4/78	3.4	4,070	599.3
BM-26	6/77 - 4/78	1.7	13.6	6.9
BM-27	6/77 - 4/78	<1	5.2	2.8
BM-28	6/77 - 4/78	<1	7.4	3.2

pH

The range of pH in ground water from springs, seeps, wells, and mines is 6.7 to 9.3. Most values fall between 7 and 8, indicating neutral to moderately alkaline conditions. High pH values are relatively common in the arid western United States and reflect the geochemistry of the dominant stratigraphic units. The pH of 9.3 is from B-121, a recently completed monitoring well in Alrad Canyon and is the only recorded pH greater than 9. The lowest pH was also from a well, MC-205 in Sowbelly Gulch. Where both acidity and alkalinity have been determined, alkalinity is typically 5 to 10 times acidity.

Nitrogen and Phosphorus

Nitrate is the only form of nitrogen consistently monitored. The average nitrate level in spring B-71 in Panther Canyon is 6.6 mg/L and the lowest reported concentration is 5.5 mg/L. As much as 9 mg/L nitrate has been detected at station BM-25 in the Royal Mine, and nitrite also was detected consistently at that location. In addition to B-25, water samples from springs B-41, B-71, and B-262 and wells B-331 and 331A have had detectable nitrite, but nitrite has been below the detection limit at most locations. For comparison, nitrate is considered an indicator of pollution in concentrations greater than 4 mg/L (as N) in many classes of surface water.

Phosphate (as phosphorus) concentrations in excess of 0.05 mg/L, considered an indicator of pollution for Class 2A, 2B, 3A and 3B waters, have been found in springs B-241, B-262, and B-32, on the east side of the CIA. In the Royal Mind, analysis reports show ortho phosphate concentrations from two of the sampling locations and total phosphate concentrations at all four locations are consistently above 0.05 mg/L: no analyses for phosphates were done for the #3 Mine. Total phosphate is also high at drill holes MC-205 and MC-206 and at spring MC-207

Ground Water Quantity

Average flow from springs B-32 and B-33 in Mathis Canyon has been 0.02 cfs. Otherwise, flow of springs and seeps that have been monitored is small, generally on the order of 0.001 to 0.01 cfs. Recharge for most of these springs and seeps probably originates in the small surface depressions or basins in the immediate vicinity. Higher flows occur during spring snowmelt, and flows in the autumn are often lower by an order of magnitude. Some seeps dry completely during the summer. Flows are also sensitive to the amount of precipitation during the winter. (Are there data to back these statements?)

Wadell (1987) documented average baseflow of approximately 0.2 cfs of from the Blackhawk-Starpoint aquifer to the creek in Spring Canyon, mainly through the Starpoint Sandstone. However, in Willow Creek Wadell detected approximately 0.4 cfs baseflow from the North Horn Formation, with only approximately 0.1 cfs baseflow from all underlying strata, including the upper Blackhawk Formation. Wadell did not determine baseflow for the Price River.

Ground water was intercepted in each of the 1994 drill holes. Several strata flowed water at up to 7 gpm. One thinly-bedded sandstone unit flowed 15 to 20 gpm, but significant gas and gas pressure encountered in this interval was possibly exaggerating actual ground water flow rates. B-331/331A was a dual completion because of inflows of 1 to 5 gpm at multiple depths in the original drill hole. A pump tests in two of the four 1994 holes indicated a recharge rate of about 0.25 gpm.

Water is found in old mine workings, and some of the old workings are now flooded, but inflow occurs as small volumes from roof drippers or through the floor. Flow rates have been recorded for the #3 Mine and three of the four Royal Mine in-mine monitoring points. The largest average flow reported is 0.04 cfs at the #3 Mine, and for the three Royal Mine stations the averages are 0.01 cfs or less. No significant point sources have been identified by CPMC.

V. IDENTIFICATION OF HYDROLOGIC RESOURCES

(IDENTIFY HYDROLOGIC RESOURCES THAT ARE LIKELY TO BE AFFECTED AND DETERMINE WHICH PARAMETERS ARE OF IMPORTANCE FOR PREDICTING FUTURE IMPACTS TO THOSE HYDROLOGIC SYSTEMS.)

A number of individuals, water user associations, government agencies, and corporate entities hold surface water rights on the Price River, Willow Creek, and some of the larger tributary drainages. There are filings for 66 surface water rights: 54 for stockwatering and 12 for various combinations of stockwatering, irrigation, domestic, industrial, municipal, power, mining, and "other". Most perennial and ephemeral streams in the CIA have water rights filed on them, many dating to the 1860's.

Ground water rights have been filed on alluvial/colluvial wells in area drainages, shallow wells that intercept perched aquifers, mine tunnels, and numerous small springs and seeps. Of the 51 ground water rights filed, 28 list municipal as the use, but many of those are unapproved rights filed by the Price River Water Improvement District on poor quality water from the methane extraction wells. Stockwatering, industrial, domestic, and "other" are listed as uses for the remainder of the water rights. Springs and seeps are also important to wildlife, though there are no filed rights that declare this as a use.

Actual ground water use within the hydrologic basin is primarily large volume municipal and irrigation use and small volume stock watering applications. Of the four primary aquifer systems, only the alluvial/colluvial aquifer yields sufficient water to serve as a reliable source of water for beneficial use. Water supply wells in alluvium along the Price River produce from the shallow, unconfined aquifer that is interconnected with the river. Along the Price River valley, especially near Heiner, Martin, and Helper, numerous individuals and corporations have significant water rights that are used for irrigation purposes. Water rights have been filed on some of the very small stock-watering ponds scattered throughout the area. The ponds are typically associated with a spring in the upper reaches of small, ephemeral watersheds such as Panther, Deep, Buck, Mathis, and Dry Canyons.

The Price River Water Improvement District extracts water for municipal use from ground water wells in Sections 23 and 24 of T. 12 S., R. 10 E. PacifiCorp owns significant water rights for water from their UGW well located in Section 35 of T12S, R9E. Water rights have been filed on mine inflow or stored mine water in four mines in the area.

The Willow Creek and Castle Gate permit areas include both municipal and non-municipal watershed areas. The Price Water Supply and Treatment Plant is located next to the Price River, across from Bear Canyon and near the abandoned Royal townsite. The Price River and associated tributaries above the water treatment plant are considered a municipal watershed, but areas downstream from the plant are not within the municipal watershed.

Recharge for springs and seeps in the CIA probably originates in small drainages or basins in the immediate vicinity. Fractures may be only locally important in recharge and ground water flow, but flows into the mines that persist for more than 30 days should be considered as possibly intercepting surface water through a natural or subsidence induced fracture system. Perched systems have limited storage and recharge capacities, and when they are intercepted by mining operations the resulting in-mine flows decline rapidly. Draining of perched systems may cause individual springs or seeps to disappear but should have little impact on the hydrologic balance of the area.

Operations in the mines can cause drawdown of the potentiometric surface of the regional aquifer, which can in turn induce increased recharge and downward flow through the overlying unsaturated zone. This would probably have a minimal or undetectable effect on perched aquifers and soil moisture because of the generally low hydraulic conductivity of the Blackhawk Formation. The cone of depression and any resulting effects on overlying unsaturated or saturated strata will diminish with time after mining ceases.

The Class 3A waters in the CHIA, which are the Price River and its tributaries above the Price Water Supply and Treatment Plant, are protected for cold water species of game fish and other cold water aquatic life including the necessary aquatic organisms in the food chain. Below the water treatment plant the Price River and its tributaries, which include Willow Creek, are Class 3C, protected for nongame fish and other aquatic life. Willow Creek and the Price River are considered by UDWR to be Class 4 fisheries, which are streams with low recreational fishing potential. Game fish species expected to occur in Willow Creek include rainbow trout, Yellowstone cutthroat trout, and brown trout, but habitat are limited. Spawning conditions are poor in lower Willow Creek, but the sporadic occurrence of trout in this part of the stream is perhaps related to seasonal spawning migrations. Adult trout may move from the Price River into Willow Creek and other tributaries during their spawning periods, and after spawning migrate back to the Price River.

Periods of high suspended solids in the streams are normally also periods of high runoff, so fine sediments are flushed from the streambed and clean gravel beds for trout spawning are left. When runoff is low, fine sediments may remain and make spawning gravels unavailable. Fine sediments increase trout egg and fry mortality through suffocation. Invertebrates are also impacted by sedimentation through loss of habitat or mortality. Invertebrate diversity may decrease but resistant or adaptive species will remain. Impacts on invertebrates may reduce the supply of food for fish. Construction, mining, and other activities can produce the same negative impacts by decreasing flow or increasing sedimentation beyond the capacity of the stream to flush itself. Coal fines have the same negative impacts as natural, fine sediments. The nature of the streambed below the mines has not been characterized.

Toxic materials in the water will reduce trout and invertebrate populations through mortality or avoidance. Nitrite concentrations in excess of 0.06 mg/L result in trout mortality. The long term LC_{50} exposure level for trout to nitrate is 1060 mg/L. Phosphorus in excess of 0.04 mg/L is not toxic to trout but does lead to eutrophication. There is no water quality standard for TDS for aquatic wildlife, but 1200 mg/L is the limit for agricultural use.

Table 20 lists potential impacts to the hydrologic resources, indicates if there is a possibility for cumulative impact outside the permit areas, and identifies analytical parameters or other indicators that need to be monitored to track potential impacts of the permitted mines.

Table 20

POTENTIAL HYDROLOGIC IMPACTS	Possible Cumulative Effect Outside Permit Areas	Parameters of Importance and Other Indicators for Predicting Future Impacts
• *Increased sediment yield from disturbed area* - Alteration or loss of fisheries in streams. Coal spillage from hauling operations and storage. Loss of riparian habitat.	YES	• Sediments • Fish and Macroinvertebrates
• *Flooding and streamflow alteration* - increase or decrease in streamflow.	YES	• Flow • Sediments • Fish and Macroinvertebrates
• *Contamination of ground water and surface water from acid- and toxic-forming materials* - Contamination of surface water from coal hauling operations and storage. Hydrocarbon contamination from above-ground storage tanks or from the use of hydrocarbons in the permit area. Contamination from road salting. Gypsum used in dust control contaminating mine discharge. Nutrients in mine discharge.	YES	• Sediments • TDS • pH • Nutrients • Specific cations and anions • Oil and Grease • Fish and Macroinvertebrates
• *Subsidence damage to springs and streams* - Increased sediment load, diminution of flow, physical barriers to fish migration.	YES	• Flow • Sediments • Fish and Macroinvertebrates
• *Alteration or destruction of fisheries and aquatic habitats* - Loss of flow, loss of access to stream, loss of fish spawning habitat, increased sediment load, acute or chronic toxicity, eutrophication, loss of food supply.	YES	• Flow • Sediments • Fish and Macroinvertebrates • TDS • pH • Nutrients • Specific cations and anions
•*Loss of ground water or surface water availability* - water rights, wildlife uses.	YES	• Flow
• *Reduction of flow due to interbasin transport of intercepted water.*	NO	• Flow

VI. MATERIAL DAMAGE CRITERIA - RELEVANT STANDARDS AGAINST WHICH PREDICTED IMPACTS CAN BE COMPARED.

Water within the CIA is used for watering livestock and wildlife, mining coal, domestic use, fisheries, and recreation. Downstream, the water is additionally used for irrigation and domestic and industrial needs. Land within the CIA is used for wildlife habitat, grazing, recreation, and mining coal. Anticipated post-mining uses are for wildlife habitat, grazing, and recreation.

Quality

Water quality standards for the State of Utah are found in R317-2, Utah Administrative Code. The standards are intended to protect the waters against controllable pollution. Waters, and the applicable standards, are grouped into classes based on beneficial use designations.

Above the Price City Price Water Supply and Treatment Plant, water in the Price River and its tributaries is classified by the Utah Division of Water Quality as:

- 1C - protected for domestic use with prior treatment,
- 2B - protected for recreational uses except swimming,
- 3A - protected for cold water species of game fish and other cold water aquatic life,
- 4 - protected for agricultural uses.

Below the water treatment plant the water is classified as:

- 2B - protected for recreational uses except swimming,
- 3C - protected for non game fish and other aquatic life, and
- 4 - protected for agricultural uses.

Surface waters located within the outer boundaries of a USDA National Forest, with specific exceptions, are designated by the Utah Division of Water Quality as High Quality Waters - Category 1 and are subject to the state's antidegradation policy. This antidegradation policy is that waters shall be maintained at existing high quality and new point source discharges of wastewater, treated or otherwise, are prohibited (Utah Administrative Code, R317-2-3.2 and R317-2-12.1). None of the lands within the CIA are USDA Forest Service lands, so these additional restrictions do not apply.

The Utah Department of Environmental Quality, Division of Water Quality can authorize a coal mine to discharge into surface waters under the Utah Pollutant Discharge Elimination System (UPDES). The permits for the mines contain site-specific limitations on total dissolved solids, total suspended solids (or total settleable solids for precipitation events), iron, oil and grease, pH, plus any other water quality parameters for which monitoring is determined necessary by the Division of Water Quality.

Water quality standard for nitrate in Class 1C waters is 10 mg/L. Nitrate levels above 4 mg/L are considered an indicator of pollution, usually from sewage, in all waters. For trout, the long term LC_{50} exposure level to nitrate is 1060 mg/L.

There is no water quality standard for nitrite, but concentrations in excess of 0.06 mg/L produce mortality in cutthroat trout (UDWR, 1988).

The water quality standard for Class 3A waters for phosphorus is 0.05 mg/L. Levels in excess of 0.04 mg/L are not toxic to trout but are excessive and promote eutrophication (UDWR, 1988). By state standards for Class 1C, 2A, 3A, and 3B waters, phosphate in excess of 0.05 mg/L is a pollution indicator.

There is no water quality standard for oil and grease, but UPDES permits typically have a limit of 10 mg/L. A 10 mg/L oil and grease limit does not protect fish and benthic organisms from soluble oils such as those used in longwall hydraulic systems, and UDWR has recommended soluble oils be limited to 1 mg/L (Darrell H. Nish, Acting Director UDWR, letter dated April 17, 1989 to Dianne R. Nielsen, Director UDOGM).

There is no water quality standard for TDS for aquatic wildlife, but 1200 mg/L is the limit for Class 4, agricultural use.

The National Academy of Sciences recommends suspended sediment limits of 26 to 80 mg/L to provide moderate protection of fish populations.

The maximum temperature for Class 3A waters is 20 degrees C (68 degrees F). The maximum allowable change for Class 3A waters is 2 degrees C (3.6 degrees F).

Physical or chemical indicators alone do not fully evaluate water quality in streams. Macroinvertebrates are excellent indicators of stream quality and can be used to evaluate suitability of a stream to support a trout fishery and other aquatic life. Cutthroat trout populations in particular are excellent indicators of stream quality. Baseline studies of aquatic habitat and biology in 1994 and 1995 provide standards against which actual stream conditions can be evaluated.

Sedimentation

Changes in sediment size distribution in streams can be determined by comparison with past studies. Winget (1980) identified 15% or more of materials finer than 0.85 mm in diameter as a critical measure of biotic potential, that is whether or not fish eggs and fry and many macroinvertebrates would be suffocated.

Interbasin Diversion

There will be no interbasin diversion of water in the CIA covered by this CHIA.

VII. ESTIMATE OF THE IMPACTS OF MINING ON THE HYDROLOGIC RESOURCES

CPMC's planned mining and related activities have the potential to generate temporary impacts to surface water resources. These impacts will typically be localized, being confined to those segments of area drainages directly impacted by mining activities, although in some cases impacts may have the potential to also effect downstream drainage areas. New surface disturbance associated with the Willow Creek mining and related operations will involve a relatively limited area, and potential mining related surface water impacts are small. Potential surface water impacts should be effectively mitigated through control of diversion of surface water for mine water supply, operation of a comprehensive drainage and sediment control system, compliance with monitoring requirements and discharge effluent standards under the required UPDES permits, and reclamation of surface disturbance areas and restoration of surface drainage characteristics.

Changes in Streamflow - Loss of Surface Water Availability

Mining, related coal processing operations, and support activities will require a consistent water supply with adequate capacity to meet all operational mine water supply requirements. Based on preliminary estimates of anticipated mine inflow volumes and mine water use requirements, it is anticipated that most if not all mine inflows can be either recycled through the operational mine water system or stored underground. CPMC plans to construct a 750,000 gallon mine water storage tank and will have significant additional mine water storage capacity in inactive areas of the underground mine workings. This storage capacity can be utilized to good advantage during seasonal low flow periods to limit required stream withdrawals. If it becomes necessary to discharge any excess mine drainage to the surface, discharge will be routed through the drainage and sediment control network to Sedimentation Pond 001 where it will be retained, treated if necessary, and sampled prior to discharge. Given that potential mine water discharge requirements are expected to be minimal, any potential changes in streamflow resulting from mine water discharge should be minimal.

Recycling of mine drainage to supplement the operational mine water system will significantly reduce requirements for diversion of surface water. Additional mine water requirements will be supplied from a point of diversion on the Price River using CPMC's existing active water rights and through recycling of mine inflows. Anticipated mine water supply withdrawals are projected at 730 acre feet per year (1.0 cfs) which is only 0.9% of the average annual streamflow for the Price River (81,140 acre feet per year based on an average flow of 112 cfs). Use of the Price River as a water supply source has the potential of reducing stream flow downstream of the point of diversion, however, any reductions will be on the order of the historic reductions associated with the Castle Gate Mine and previous mine operations by previous operations. CPMC does not anticipate that the full amount allowed under the existing water rights will actually be withdrawn and the available excess will serve as an effective buffer to limit potential impacts on downstream flows.

Potable and sanitary water requirements will be addressed through a water supply connection to the existing Price River Water Improvement District water main located in Price Canyon.

Sedimentation ponds tend to reduce discharge flow volumes and extend the period of effective flow from snowmelt and thunderstorm events, which are the source of most runoff in the Willow Creek area. Most retained runoff is returned to the surface drainage system. Minor alteration of the timing of runoff flows is significant only if the delay and the corresponding volume of retained runoff reduces flows during critical low flow periods or if the deferral of runoff discharge involves significant time delays. With the exception of Pond 003, which is designed as a non-discharging structure, the Willow Creek Mine sedimentation ponds are designed to gradually release impounded runoff following required retention for sediment control. Maximum designed detention time is only 3.4 days, with discharge occurring continuously once the pond level reaches the discharge orifices. Sedimentation Pond 003 is designed with a maximum storm retention capacity of only 0.41 acre-feet, which is a negligible amount relative to flow volume for the receiving watershed.

There should be no noticeable change of flow in Willow Creek or the Price River. Because most erosion occurs during spring runoff, there should be little change in erosion or in the ability of the streams to flush themselves of fine sediment periodically.

Subsidence Damage to Springs and Seeps - Loss of Ground Water Availability

The Willow Creek Mines are designed to restrict subsidence to the permit areas; however, where overburden is minimal or fracturing is extensive, there is potential for the capture of ground water or surface water by subsidence cracks. Ground water impacts resulting from the planned mining and related activities will be minimal due to limited ground water occurrence, low overall permeabilities and consequent limitations on the effective area of influence, and the low level of beneficial ground water use in the potentially affected areas. In particular, potential subsidence effects on perched ground water systems and associated springs and seeps are expected to be negligible due to the isolated nature of such ground water occurrences. Ground water diverted from seeps or springs fed by perched systems would most likely emerge nearby at another surface location rather than drain down into the mine. Subsidence impacts are largely related to extension and expansion of existing fracture systems and upward propagation of new fractures. Vertical and lateral movement of ground water in the permit area appears to be largely controlled by fracture conduits, so readjustment or realignment of the conduit system may potentially produce changes such as increased flow along fractures that are enlarged and diversion of flow along new fractures. Increased flow rates would potentially reduce residence time and improve water quality. Some of the perched, localized aquifers could be dewatered.

There is little potential for the effects from dewatering perched aquifers to extend beyond the permit area because the perched aquifers of the Blackhawk Formation are lenticular and localized, the stratigraphic sequence has low overall permeability and lacks significant vertical hydraulic continuity, and the proposed mining operations will be relatively deep.

Where mining and subsidence occur within the saturated rocks of the regional aquifer there will be a large increase in permeability locally. Sealing of subsidence cracks by clays in the Blackhawk is expected to minimize long term effects of subsidence on the hydrologic systems. With time, permeability will decrease as fractures close and the potentiometric surface establishes a new equilibrium. Residual impacts should be restricted to the previously mined area and will probably be negligible.

Temporary increases in runoff from surface disturbance areas

In general, probable hydrologic consequences for surface water resources resulting from CPMC's mining operations will be limited by the relatively small mine facilities areas. Impacts will be effectively mitigated by operation of the drainage and sediment control system and ultimate reclamation of mine disturbance areas.

Proposed new mining related surface disturbance will involve removal of vegetation and soil/substitute materials and grading of disturbance areas for specific mining related uses. These disturbance activities will reduce infiltration potential and evapotranspiration due to elimination of vegetation and will increase surface runoff and erosion potential. For existing disturbance areas within the Castle Gate preparation plant and loadout area and the Crandall Canyon facilities area these impacts have already occurred and runoff effects are ongoing. Total runoff from all mine disturbance areas including the mine facilities area, Castle Gate preparation plant and loadout area, and the Crandall Canyon facilities area, for the 10-year, 24-hour storm event is only 9.14 acre-feet, which can be compared with a total average annual runoff volume of 81,140 acre-feet for the Price River.

On completion of mining operations, disturbed areas will be reclaimed by backfilling and grading, reestablishing natural drainage patterns, replacing soils or soil substitutes, and revegetation. It is anticipated that reclamation will effectively restore infiltration and runoff patterns to baseline conditions currently existing for the surface disturbance areas.

Changes in surface water chemistry

Runoff from surface disturbance areas, infiltration and drainage from coal refuse and mine waste storage areas, and surface discharge of excess mine drainage may result in changes in runoff water chemistry. The most probable potential change in runoff water chemistry would be a shift toward a sodium sulfate type due to the weathering and leaching of exposed materials.

CPMC's proposed surface drainage and sediment control measures will be effective in limiting exposure of runoff to disturbed materials and consequent leaching. None of the materials that will be exposed, including overburden, soils, coal refuse, and mine waste materials, have been conclusively documented to be potentially acid- or toxic-forming. While minor changes in runoff water chemistry may occur as a result of mining and related operations, limited surface disturbance areas and small disturbed area runoff volumes will minimize the potential for significant changes in water chemistry for the receiving drainages. Disturbed area runoff flows will be diluted by significantly greater volumes of runoff from other drainage basin areas.

Increases in the levels of TDS, TSS, and certain individual chemical constituents

Surface water in the mine area is generally neutral to moderately alkaline with naturally elevated levels of TDS, TSS, sulfate, iron, and phenols. A probable consequence of surface disturbance and the resultant erosion will be increases in sediment loading and TSS levels for the disturbed area runoff. Contact between disturbed area runoff and materials exposed to weathering and oxidation, drainage from coal refuse and mine waste storage areas, and discharge of excess mine drainage flows may result in increases in TDS and in individual chemical constituents. Mining and related activities will probably not result in any significant change in surface water pH, although TDS, TSS, and sulfate levels may increase slightly. The restricted size of the disturbed area, small runoff volumes, and mitigation measures have the potential to limit increases in TSS, TDS, and individual chemical constituents. Potential increases may be effectively addressed on a short-term basis by establishment and operation of the drainage and sediment control system and compliance with monitoring requirements and discharge effluent limitations of the UPDES permit. Reclamation and restoration of effective surface drainage conditions should address potential mining and related surface water impacts over the long-term.

Potential Effects on Aquatic and Riparian Resources, Including Sensitive Species

The primary potential impacts on fish and aquatic species, aquatic habitat, and riparian vegetation that may result from the mining and related activities include; 1) Sedimentation from construction activities; 2) Temporary loss of low quality habitat and limited riparian vegetation as a result of realignment of portions of the Willow Creek channel, construction of the primary access road bridge, and replacement of an existing culvert crossing; and 3) Any significant changes in stream water quality or flow rates. Secondary potential impacts include risks associated with petroleum spills or leaks from equipment used near the stream and minor fugitive coal dust or coal sediment inputs to the stream resulting from coal handling and other mining related operations.

Scheduling of required construction activities during the seasonal low flow period and the use of alternative sediment controls should effectively minimize potential sediment contributions and impacts on fish movements or migrations. Sediment contributions from construction of mine surface facilities will be controlled by a combination of temporary control measures and designed drainage and sediment control structures to be established prior to construction disturbance.

Realignment of two stream segments will result in the temporary loss of low quality habitat and riparian vegetation. The existing segments of the Willow Creek channel that are to be realigned represent habitat for benthic macroinvertebrates and resident fish such as mountain sucker and speckled dace, are migratory routes for several trout species, and support limited riparian vegetation in a thin zone bordering the channel margins. Potential habitat exists for two Federal candidate (Category 2) species, roundtail chub and leatherside chub, in Willow Creek. Habitat for three Federal candidate (Category 2) species (roundtail chub, leatherside chub, and flannelmouth sucker) exists in the Price River, although the closest known occurrence of any of these species is approximately 70 miles downstream on the Green River.

Planned stream realignments will reduce the total length of existing stream habitat by approximately 110 feet. Assuming an average stream width of 6 feet at low flow, the amount of stream habitat disturbed would be approximately 7,260 square feet. Stream realignment will also impact approximately 1.5 acres of riparian vegetation. Shallow riffle habitats with clay, silt, rubble, and boulder substrates are characteristic of Willow Creek within the proposed mine facilities area. Overall aquatic habitat quality and value are limited primarily by the clay and silt deposits. Pool habitat is generally limited in terms of depth and areal coverage except for the series of five man-made pools, located below the existing culvert crossing, that are to be removed in conjunction with construction of the lower stream channel realignment and new culvert crossing. The loss of existing stream habitat and riparian vegetation will be effectively mitigated by construction of designed channel segments and revegetation. Designed channel segments will have essentially the same hydrologic and geomorphic characteristics as the existing stream segments they will replace, yet they will incorporate specific design considerations and construction practices that will, overall, enhance the aquatic and riparian habitat values.

Construction activities for the main access road bridge and replacement of the existing culvert crossing will result in a relatively limited, temporary disturbances to aquatic and riparian habitats. The estimated area of disturbance is approximately 300 square feet at each location. Construction is to occur during low flow, and disturbed areas would be returned to their approximate pre-disturbance condition and configuration following completion of construction activities .

The use of construction equipment near the Willow Creek stream channel represents a potential risk because a petroleum spill or leak could result in stream contamination with potential toxic effects on fish and macroinvertebrates. The magnitude and duration of the impact would depend on the location and amount of the spill, the type of material spilled, and flow conditions at the time of the spill. No long term damage is to be expected , but short term effects to aquatic habitats and all forms of life in the stream could be catastrophic.

Stormwater runoff from disturbed areas is a potential source of additional sediment contributions to Willow Creek. Sediment contributions should be effectively controlled by construction, operation, and maintenance of drainage and sediment control systems. Siltation and erosion are existing problems in the lower portion of Willow Creek and it is important to minimize additional sediment inputs. Previous water quality studies for Willow Creek have resulted in reported total suspended solids levels ranging from about 5 to 700 mg/L, with an average of 363 mg/L (USDI BLM 1992). A limit of 26 to 80 mg/L suspended sediment has been recommended as the limit for moderate protection of fish populations. Implementation of drainage and sediment control measures as described in the PAP should keep suspended sediments within background concentrations, and mining related sediment contributions would result in little or no significant impact on fish and macroinvertebrate communities or aquatic habitat values.

To the extent reasonably feasible within topographic limitations, coal storage and handling facilities and equipment have been located as far as possible from Willow Creek and the Price River. Wind-blown dust from the stockpiles could deposit coal dust in or near stream channel areas. The conveyor system will be covered to minimize exposure and dispersion of coal fines during transport and all transfer points will be partially or fully enclosed and will incorporate Best Available Current Technology (BACT) emission controls. Small amounts of coal dust or fines will probably escape from the conveyor system and minor spillage may occur in the area immediately adjacent to the conveyor. Most of the conveyor system will be at least 200 feet from Willow Creek, which will minimize the potential for coally material to enter the stream. Approximately 1200 feet of the conveyor system will be located within 150 to 180 feet of the stream. The planned realignment of two sections of Willow Creek will increase the effective distance between the creek and the conveyor. A 100 foot stream buffer zone and, where feasible, a full-length protective berm are to be established between the mine facilities and stream channel. While coal dust and other coally materials may be deposited in or near Willow Creek and the Price River, potential associated impacts to aquatic communities or habitat values are anticipated to be negligible due to the limited amounts and the relatively inert nature of the coal.

A Section 7 consultation process under applicable U.S. Fish and Wildlife Service regulations is anticipated to be part of the review process for the Federal Mine Plan Approval associated with the Federal leases. In the event such consultation results in a determination that the proposed water use represents a new depletion, a biological assessment of potential effects on endangered fish species and associated critical habitat designations in the Green and Colorado Rivers would be completed. Three Federal candidate Category 2 species (roundtail chub, leatherside chub, and flannelmouth sucker) for which both the Price River and lower portions of Willow Creek may provide potential habitat would be included in any biological assessment.

VIII. MATERIAL DAMAGE DETERMINATION

Increased Sediment Yield

Fine sediments in Willow Creek may increase as a result of road construction and coal mining activities, with a notable increase in coal fines during the period of mine operation. Because clay and silt deposits are common in the Willow Creek stream substrate, the impact of the increase in fine sediments should be negligible. After mining and reclamation activities cease, Willow Creek should be able to flush itself of excessive fine sediments. No material damage from increased sediment yield is expected.

Flooding or Stream Flow Alteration

Potential mine water discharge requirements are expected to be minimal. Use of the Price River as a water supply source has the potential of reducing stream flow downstream of the point of diversion, however, any reductions will be on the order of the historic reductions associated with the Castle Gate Mine and previous mine operations. There should be no noticeable change of flow in Willow Creek or the Price River. Because most erosion occurs during spring runoff, there should be little change in erosion or in the ability of the streams to flush themselves of fine sediment periodically. There is no present or foreseen material damage resulting from changes in flow due to present or projected discharge from the mines or withdrawals of water from the streams.

Water Quality

Water quality problems are not expected from construction or operation of the mine and related facilities. No material damage to water quality is expected.

Subsidence Damage to Springs and Seeps

There is little potential for the effects from dewatering perched aquifers to extend beyond the permit area because the perched aquifers of the Blackhawk Formation are lenticular and localized, the stratigraphic sequence has low overall permeability and lacks significant vertical hydraulic continuity, and the proposed mining operations will be relatively deep. No material damage to springs or seeps from subsidence or other coal mining activities is expected.

Alteration or Destruction of Fisheries and Aquatic Habitat

Short term disruptions to sections of Willow Creek aquatic habitat are expected during construction of mine facilities. No material damage to fisheries or aquatic habitat is expected.

Loss of Ground Water or Surface Water Availability

There should be no noticeable change of flow in Willow Creek or the Price River. There is little potential for effects from dewatering of aquifers to extend beyond the permit area because perched aquifers are lenticular and localized, the stratigraphic sequence has low overall permeability and lacks significant vertical hydraulic continuity, and the proposed mining operations will be relatively deep. No material damage from loss of surface or ground water availability is expected.

IX. STATEMENT OF FINDINGS

No evidence of material damage from actual mining operations has been found. No probability of material damage from actual or anticipated mining operations has been found.

X. REFERENCES

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